NDUSTRIAL LIGHTING CODE

FOR

FACTORIES, MILLS, OFFICES AND OTHER WORK PLACES

THIRD EDITION—REVISED

ISSUED BY THE

INDUSTRIAL COMMISSION OF WISCONSIN

MADISON, WISCONSIN
Democrat Printing Company, State Printer
1921

Industrial Commission of Wisconsin

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Industrial Lighting Code Not a Hardship on Employers

Although most factory managers consider lighting as an expense, it should be looked upon as an instrument of production.

A few managers have found from experience, that when the lighting is made very good, it advances into a class with income producing investments.

They have learned that three or four times the amount of lighting ordinarily used has a remarkably beneficial influence on production.

The increased cost of such "productive lighting" is only a fraction of the value of the extra goods produced.

The reason for this should be easy to understand. The production of any skilled workman depends upon his speed and accuracy.

Give him poor light and he is hampered in his work. Give him good light and those frequent little delays, so inescapable with poor light are eliminated, and he works more accurately.

Moreover, the workman is not particularly conscious of his increased efficiency. He works along as usual, but because the lighting is right, he just naturally is faster and more accurate.

If this is true, and experience proves it to be true, is not "productive lighting" of *paramount interest to every factory manager?*

Of course the state has set certain legal minimum standards of lighting for factories, mills and other work places, for the protection of the eyesight of the workman and to decrease industrial accidents. Therefore every industrial manager is compelled to interest himself in factory lighting to the extent of meeting at least the legal minimum standard in his works.

However, the legal minimum standards are only a fraction of the "productive lighting" standards.

Therefore any manager who installs "productive lighting" in order to gain its benefits of increased production, will find that he has automatically taken care of the requirements set forth by the Industrial Lighting Code.

INDUSTRIAL COMMISSION OF WISCONSIN.

Fig. 1—Lighting such as this is better than the Industrial Lighting Code requires. The code specifies the minimum requirements for safety and conservation of vision, but the advanced employers know from experience that good illumination generously supplied, brings handsome returns in increased production and decreased spoilage. The lamps used in these shops are mercury vapor. (See also Fig. 19.)

Fig. 2.—The light ceiling adds much to the favorable appearance of the lighted room, increases the useful illumination at the work, and reduces brightness contrasts, in this paper box factory.

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PART I

Industrial Lighting Code for Factories, Mills, Offices and other Work Places

INTRODUCTION

In January, 1913, the Industrial Commission adopted general orders on sanitation, which included a group of "shop lighting" orders, but experience in enforcing the latter proved the desirability of modifying and extending their scope.

Therefore in July, 1917, the Industrial Commission appointed a committee to assist in formulating a revised lighting code for factories, mills, offices and other work places. The personnel of this committee was as follows:

F. M. Wicks, Westinghouse Lamp Co., Milwaukee, Chairman.
Davis H. Tuck, Illuminating Engineer, U. S. P. H. S.
J. R. Finn, Cutler-Hammer Co., Milwaukee.
Howard Ilgner, Bureau of Illumination Service, Milwaukee.
M. A. Freschl, Holeproof Hosiery Co., Milwaukee.
Geo. F. Rohn, Electrical Contractor, Milwaukee.
H. G. Monger, T. M. E. R. & L. Co., Milwaukee.
R. B. Brown, Milwaukee Gas Light Co., Milwaukee.
Dr. Claude S. Beebe, Milwaukee.
John A. Hoeveler, Electrical Engineer, Industrial Commission, Secretary.

This committee held a number of meetings and consulted the following authorities on industrial lighting:

1. Committee on Lighting Legislation of the Illuminating Engineering Society. L. B. Marks, Chairman.
2. Special Sub-committee of the Illuminating Engineering Society appointed to assist Industrial Commission of Wisconsin. Ward Harrison, Chairman.
3. Francis A. Vaughn, Consulting Engineer, Milwaukee.
4. T. F. Foltz, Mechanical Engineer. Department of Labor and Industry of Pennsylvania.
5. Lewis T. Bryant, Commissioner of Labor of New Jersey.
6. Arthur J. Sweet, Consulting Engineer, Milwaukee.

The orders finally formulated by the committee are based upon the advice received from these sources and independent

investigations of committee members. They are definite, clear and practical. Hence employers will find them simple and easy to apply.

On May 20, 1918, the Industrial Commission adopted these lighting orders pursuant to Sections 2394—41 to 2394—70, inclusive of the statutes of Wisconsin. They were published in the official state paper on May 27, 1918, and became effective on the dates indicated in the orders. Amendments in phraseology were made in Orders 2112 to 2114, inclusive, on October 17, 1919, which became effective November 24, 1919. Additional minor amendments were made on November 20, 1920, and these became effective December 20, 1920.

Industrial Lighting Code for Factories, Mills, Offices and Other Work Places

SECTION I. APPLICATION AND DEFINITIONS.

Order 2100. Application. This code shall apply as a minimum requirement for the natural and artificial lighting of all factories, mills, offices and other work places.

Order 2101. Meaning of Terms. In this code:

(1) Candle (or candle-power) means the unit of luminous intensity maintained by the national laboratories of the United States, France and Great Britain.

(2) Lumen means the unit of luminous flux equal to the flux emitted in a unit solid angle (steradian) by a point source of unit candle-power.

(3) Foot-candle means the unit of illumination equal to one lumen per square foot.

Note: The foot-candle is the lighting effect produced upon an object by a lamp of one candle-power at a distance of one foot; at two feet. the effect would be not one-half foot-candle, but one-fourth foot-candle; at three feet, one-ninth foot-candle, etc.

(4) Photometer means an instrument suitable for making illumination measurements.

(5) Lamp means that part of the lighting equipment from which the light originates.

Note: With electric lighting it means the incandescent lamp bulb or the arc, and with gas lighting, the burner and mantle.

(6) Local Lamps (or Lighting) means lighting units located close to the work, and intended to illuminate only a limited area about the work.

(7) Overhead Lamps (or Lighting) means lighting units installed above ordinary head level to secure a general illumination over a considerable area.

(8) Brightness means the intensity of light per unit area emitted from or reflected by a body; and in this code is expressed in candle-power per square inch.

(9) Glare means any brightness within the field of vision of such a character as to cause discomfort, annoyance, interference with vision, or eye fatigue.

(10) Eye strain means a physiological condition of the eye resulting in discomfort, poor vision or fatigue.

(11) Shaded means that the lamp is equipped with a reflector, shade, enclosing globe, or other accessory for reducing the brightness in certain directions, or otherwise altering or changing the distribution of light from the lamp.

SECTION II. NATURAL AND ARTIFICIAL LIGHTING.

Order 2110. General Requirement. Working or traversed spaces in buildings or grounds of places of employment shall be supplied during the time of use, with either natural or artificial light in accordance with the following orders. (2111–2118).

Order 2111. Natural Light. Side windows, skylights, saw-tooth or other roof lighting construction of buildings shall be arranged with reasonably uniform bays and the glass area so apportioned that at the darkest part of any working space, when normal exterior daylight conditions obtain, there will be available a minimum intensity equal to twice that of Order 2112 for artificial light.

Note: Normal exterior daylight conditions obtain when the average brightness of the sky is 1.5 candle-power per square inch.

Awnings, window shades, diffusive or refractive window glass shall be used for the purpose of improving daylight conditions or for the avoidance of eye strain wherever the location of the work is such that the worker must face large window

areas, through which excessively bright light may at times enter the building.

Note: The intensity requirements for adequate day lighting are much higher than those for adequate night lighting, because in general under daylight conditions, the light coming to the eye from all the surroundings in the field of vision is much brighter than at night, and hence a correspondingly more intense light must fall on the object viewed.

Order 2112. Artificial Light. When the natural light is less than twice the minimum permissible intensities of illumination set forth in the following table, artificial light shall be supplied and maintained in accordance with the table.

Note: The measurements of illumination at the work will be made with a properly standardized portable photometer.

ILLUMINATION INTENSITY AT THE WORK IN FOOT-CANDLES

Room or Space to be Illuminated	Minimum Permissible Intensities (1)	Intensities of Good Practice (2)	Productive Intensities (3)
(a) Roadways and yard thoroughfares..........	0.02	0.05 — 0.25	....
(b) Storage spaces............................	0.25	0.5 — 1.	....
(c) Stairways, passageways, aisles.............	0.25	0.75 — 2.	....
(d) Toilets and washrooms......................	0.5	1.5 — 3.	....
(e) Rough manufacturing such as rough machining, rough assembling, rough bench work, foundry floor work..................	1.25	2. — 4.	6.
(f) Rough manufacturing involving closer discrimination of detail...................	2.	3. — 6.	10.
(g) Fine manufacturing such as fine lathe work, pattern and tool making, light colored textiles.............................	3.	4. — 8.	15.
(h) Special cases of fine work, such as watch making, engraving, drafting, dark colored textiles..............................	5.	10. — 15.	25.
(i) Office work such as accounting, typewriting, etc..............................	3.	4. — 8.	15.

Note: The intensities listed in column (1) specify the lowest illumination with which workmen can be expected to work with safety and without undue eye strain.

The intensities listed in column (2) are those employed in well lighted modern factories where the aim has been to reduce eye strain to a minimum.

The intensities of column (3) are those employed in factories where the management aims at securing the maximum production and minimum spoilage.

When part daylight and part artificial light must be used together, it is particularly necessary to provide high intensity artificial light to supplement the inadequate daylight. (See note accompanying Order 2111.)

Order 2113. Shading of Lamps for Overhead Lighting. Lamps suspended at elevations above eye level less than one

quarter their distance from any position at which work is performed, shall be shaded in such a manner that the intensity of the brightest square inch of visible light source does not exceed seventy-five candle-power.

Exception: Lamps suspended at greater elevations than twenty feet above the floor, are not subject to this requirement.

Note: Glare from lamps or unduly bright surfaces produces eye strain and increases the accident hazard.

The brightness limit specified in this order is an absolute maximum. Very much lower brightness limits are necessary in many interiors illuminated by overhead lamps, if the illumination is to be satisfactory. In some cases, the maximum brightness should not exceed that of the sky (1.5 to 3.0 candle-power per square inch).

Where the principal work is done on polished surfaces, such as polished metal, celluloid, varnished wood, etc., it is desirable (but not mandatory at present) to limit the brightness of the lamps in all downward directions to the amount specified in this order.

Order 2114. Shading of Lamps for Local Lighting. Lamps for local lighting shall be shaded in such manner, that the intensity of the brightest square inch presented to view from any position at which work is performed, does not exceed three candle-power.

Note: In the case of lamps used for local lighting, at or near eye level, the limits of permissible brightness are much lower than for lamps used for overhead lighting, because the eyes are more sensitive to strong light received from below, and because such light sources are more constantly in the field of view.

Order 2115. Distribution of Light on the Work. The reflectors or other accessories, mounting height and spacing employed with lamps shall be such as to secure a reasonably uniform distribution of illumination, avoiding objectionable shadows and sharp contrasts of brightness. If local lighting is used, there shall be employed in addition, a moderate intensity of overhead lighting.

Note: When local lighting is used as the sole source of illumination of an interior, the field of illumination from each lamp is in contrast to the surrounding darkness, thereby causing eye strain and increasing the accident hazard.

Order 2116. Emergency Lighting. Emergency lamps shall be provided in all work space aisles, stairways, passageways, exits, and on all "B" fire escapes (three feet and four inches wide—See Building Code), to provide for reliable operation when, through accident or other cause, the regular lighting is extinguished. Emergency lighting systems, including all supply and branch lines, shall be entirely independent of the

regular lighting system and shall be concurrently in operation with the regular lighting.

Note: It is the intention of this order to guard against accident due to the failure of the regular lighting system, by providing sufficient illumination to enable the occupants to

1. Avoid contact with moving machinery and other danger points until the regular lighting is again put in operation.
2. To vacate the building safely and expeditiously when this is necessary because of fire or other causes.

Emergency lighting may be installed in various ways. The method to be employed depends upon the size of the premises, the extent of the hazards of employment, and the means available for supplying such emergency lighting. (See Part II, page 44.)

Order 2117. Switching and Controlling Apparatus. Switching or controlling apparatus shall be so placed that at least pilot or night lights, which may be part of the emergency lighting system, may be turned on at one or more easily accessible points. All such apparatus shall be plainly labeled for identification.

Note: The purpose of this order is to make it possible for the night watchman or other qualified persons to turn on enough lamps, when entering any portion of the premises at night, to enable them to safely see their way around without the need of a lantern or flashlight.

Order 2118. Maintenance. Windows and artificial lighting units shall be cleaned at sufficiently frequent intervals to maintain illumination in accordance with the standards of these orders. All parts of the artificial lighting system shall be frequently inspected and when found defective, replaced or repaired.

Note: Lamps with heavily blackened bulbs should be replaced even though they may still burn.

Fig. 3—Best eye protection is secured by completely concealing the light source. In this hosiery mill gas-filled tungsten lamps are equipped with indirect bowls. Although the indirect system may be more expensive in initial cost and operation, the immensely improved quality of illumination justifies its use in factories where high grade work is done and the best illumination obtainable is essential.

PART II

Helpful Suggestions on How to Comply with the Industrial Lighting Code

By

John A. Hoeveler, Electrical Engineer, Industrial Commission of Wisconsin.

Introduction

Acknowledgment is due Mr. R. B. Brown of the Milwaukee Gas Light Co. for the data on gas lighting; to Mr. Arthur J. Sweet, Consulting Engineer, Milwaukee, Davis H. Tuck, Electrical Engineer, Holophane Glass Co. Inc., New York and the engineering department of the National Lamp Works, Cleveland, Ohio, for assistance in preparing the discussion on reflectors and their application; to Mr. George C. Keech of the Cooper Hewitt Electric Company, Chicago, for data on the mercury vapor lamp, to Mr. Francis A. Vaughn, Vaughn and Meyer, Consulting Engineers, Milwaukee, for many helpful suggestions on various aspects of the work.

Enforcing the Industrial Lighting Code.

It is not assumed that a factory owner or manager should study the details of the science of illumination, to the extent of understanding the provisions of this industrial lighting code, any more than he should be required to know the details of building construction and the rules of the building code. No factory manager would attempt to do this. When he contemplates constructing a new building, he calls in an architect, explains his requirements and gives the architect authority to proceed. However, knowing that the state regulates building construction, **he instructs his architect to carry out the provisions of the building code,** with which the architect is expected to be familiar. In the same way, the lighting of the factory must be put up to those whose business it is to know and understand **the provisions of the lighting code.**

Provision for natural lighting must be made when the building is planned and this, as a rule, is the architect's work. In general, therefore, it becomes the architect's duty to see that the provisions of the lighting code are complied with in respect to natural lighting.

Provision for the artificial illumination, should preferably be made before building construction is commenced, at the time the building and the arrangement of machinery or other equipment is planned. Some one competent to interpret the provisions of the lighting code should be in charge of this work. If the owner leaves this to the architect, he should assure himself that the architect has someone in his employ competent to do the work, or that the architect will engage the services of an illuminating engineer. The competent independent consulting engineer will more than earn his fee in the savings he can effect through his specialized knowledge in the lighting field. If the factory manager personally undertakes to decide as to the lighting system to be employed, or if he places this responsibility upon his electrical department, he should at least avail himself of such commercial engineering services as can usually be obtained from the local central station, from first class electrical contractors or from reliable manufacturers of lighting equipment.

Maximum Production Through Good Lighting.

The industrial manager should clearly recognize the function of this or indeed of any lighting code. It does not specify the lighting practice which will insure the maximum production and minimum spoilage; on the contrary, it establishes the **minimum** lighting service which will sufficiently safeguard the safety and health of the employes. In practically all cases, the industrial manager will find it highly profitable to provide materially better lighting than that which will barely meet the requirements of this code. At least the intensities of column (2) in the table of Order 2112 (See page 10) should be employed, and if the benefits of increased production are to be realized in a marked degree, the intensities of column (3) should be used.

The failure to realize that really adequate lighting is something more than providing a sufficient quantity of light is today costing industrial America annual losses which can con-

servatively be stated as totaling many millions. Maximum production of the worker depends not only upon providing a sufficient quantity of light, but upon proper **quality** of light, proper direction on the work, freedom from objectionable shadows and conditions suitable for the eye to perform its functions without excessive fatigue.

Fig. 4—"Looping" is a knitting operation requiring the best illumination obtainable. Ten foot candles on the horizontal plane, on a level of the work, provide such satisfactory results that the operators prefer the artificial light to the daylight.

While the Industrial Commission cannot undertake to give each plant the specialized individual study needed to design an adequate lighting system for it, the commission will gladly give expert advice covering the broad outlines of any problem. Then if the services of a good electrician are secured to carry out the details of this advice, a good installation will be assured.

Desirable Qualities of Artificial Lighting.

In addition to adequate intensity of illumination at the work, whether in horizontal, vertical or oblique planes, moderate intensities of illumination in aisles and other spaces inter-

mediate between the working surfaces, on the walls, ceilings, etc., are necessary to safety and comfortable vision.

The use of extremely bright light sources must be scrupulously avoided, otherwise there will be harmful glare. Moreover, strong contrasts of brightness should be avoided for the same reason. Well shaded lamps and light walls, moderately illuminated, will minimize the eye strain.

Reflected images of light sources in polished surfaces must be guarded against by the use of lighting units which reduce the brightness of the lamps sufficiently in the downward directions. Such images, from excessively bright light sources, cause extremely trying glare, because of the necessity of directing the eyes toward those surfaces, and because the eyes are by nature especially sensitive to light from below.

To be satisfactory, the illumination must be such that there are no shadows so dense as to make vision difficult, where the light from one or two sources is cut off, nor so sharply defined as to cause confusion between a machine part and its shadow. Shadows should be soft and luminous.

In some cases color forms one of the most important aids to vision. The ideal source of light emits rays of all colors. Ordinary incandescent lamps give a yellowish light, but all colors are present in sufficient quantity to preserve the natural appearance of objects. Where exact color discrimination or better identification of detail through color contrasts is essential, the gas filled tungsten lamp having the blue bulb will be found useful. The blue bulb serves to screen out the excess red and yellow rays.

How to Plan the Artificial Lighting System.

Since this code requires the use of overhead lighting, even where local lighting is used as the principal source of illumination, it becomes necessary for those, upon whom falls the responsibility of designing lighting installations, to know how to meet the code requirements. A few helpful suggestions are therefore given.

In planning an artificial lighting system, the decision must first be made as to type of light source to be employed. Three types of light sources are today in general use in industrial lighting—the incandescent electric lamp, the mercury-vapor electric lamp and the mantle gas lamp. Each of these has its

merits. The mercury-vapor lamp is supplied by only one manufacturer, and this manufacturer designs the installations of his product. The following discussion of size of lamp necessary to meet Order 2112 is therefore drafted with particular reference to the electric incandescent lamp and to the mantle gas lamp.

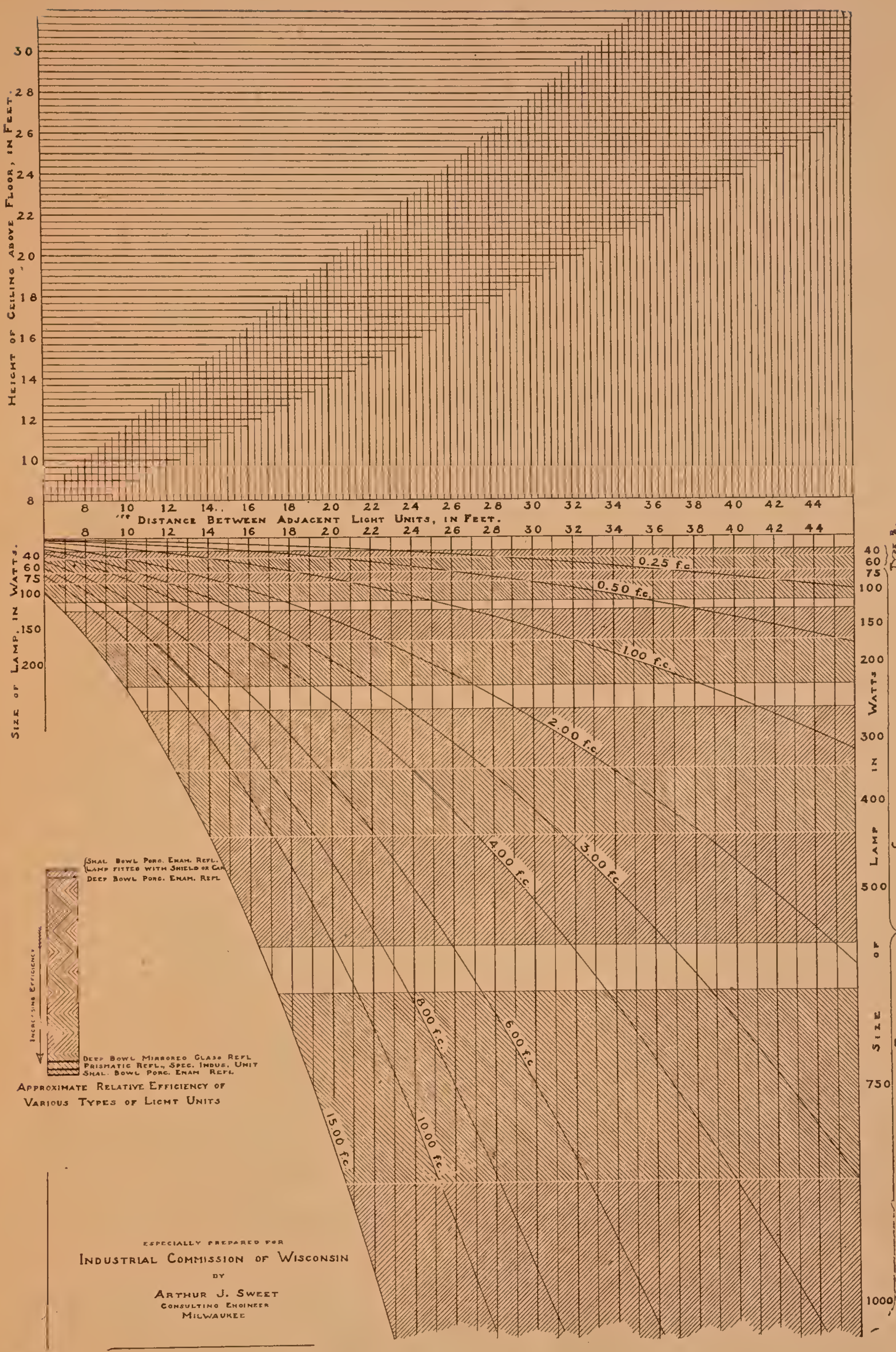
The determination of the size of lamp required to supply the specified intensity is dependent upon the spacing between light sources, and this involves a simultaneous consideration of Order 2115, "Distribution of Light on the Work." In determining the size of lamp, whether gas or electric, four items must be considered:

(a) At what height shall lamps be mounted?
(b) How far apart shall lamps be spaced?
(c) What size of lamp shall be used?
(d) What kind of reflector or globe shall be used?

Mounting Height. (Lamps.)

It will generally be found desirable to mount lamps as high as possible. The chief exceptions to this general rule consist of those cases (a) where the ceiling is very high relative to one dimension of the floor area, (b) where horizontal beams, belting or the like form a network at some distance below the ceiling, (c) where it is necessary to place lamps with reference to machines in order to get proper direction of light on the work, and (d) where a high diffusion is desired and this can best be attained by the use of diffusing type lighting units suspended relatively close to the work. The incandescent electric lamp can generally be mounted directly on the ceiling, thus bringing the light center from 6 inches to 12 inches below the ceiling. The minimum distance below the ceiling at which the mantle gas lamp can be mounted varies somewhat with the size of lamp and somewhat with the character of the ceiling. The use of a heat deflector permits the lamp to be mounted closer to wood, plaster or metal ceilings, and such use is therefore recommended. When such deflector is used, the light center of mantle gas lamps can be brought from 18 inches to 35 inches from the ceiling.

There are two chief advantages of mounting lamps as high as possible. First, higher mounting heights permit the use of wider spacings with equally good distribution of the light,



Note: This chart refers to illumination on a horizontal plane 36 inches above the floor.

Type B means vacuum tungsten lamp. Type C means gas filled tungsten lamp.

Plate I—Electric Lighting

For determining the proper spacing and size of incandescent tungsten lamps to produce any desired intensity of illumination.

such wider spacings in turn resulting in the use of a smaller number of lamps of larger size. This means lower installation and operation costs. A second advantage of higher mounting heights is that nearby lamps are less likely to come within the direct field of vision, and hence are less likely to be a source of eye fatigue and eyestrain to the worker.

Spacing between Lamps.

The upper part of Plates I and II present the data from which the proper spacing between lamps can be satisfactorily determined for the more typical or common conditions of installation. The method of such determination is illustrated by the following example:

Example: Let it be assumed that the ceiling height is 10 feet and that the above recommendations to mount the lamps as close as possible to the ceiling will be followed. Referring to Plate I, the fine horizontal line representing a 10 foot ceiling height is followed to its intersections with the vertical lines. The first and last of these intersected vertical lines show that the lamps need not be mounted closer together than 8 feet and should not be mounted further apart than 12⅔ feet. The best spacing will be the minimum of these values—in this case 8 feet. If the work is of an exacting character, the spacing should approximate this best value—in this case should not be greater than, say, 10 feet. If the work is not of an exacting character, a wider spacing may be employed, but not greater than the maximum indicated by the chart.

The exact spacing adopted will generally depend upon the dimensions of the building structure. Thus in the case of the ceiling height assumed above, if the factory building has bays whose dimensions are 20 feet by 20 feet lamps would preferably be located on 10 foot centers in both directions, thus providing 4 lamps per bay.

It should be noted that in Plate I the proper spacing of lamps is determined with respect to the ceiling height, while in Plate II the spacing is determined with relation to the height of the gas mantle above the floor. This different basis of reference is made necessary by the variations in minimum distance at which the gas lamp can be mounted below the ceiling. Of course, in those cases where the electric lamps are

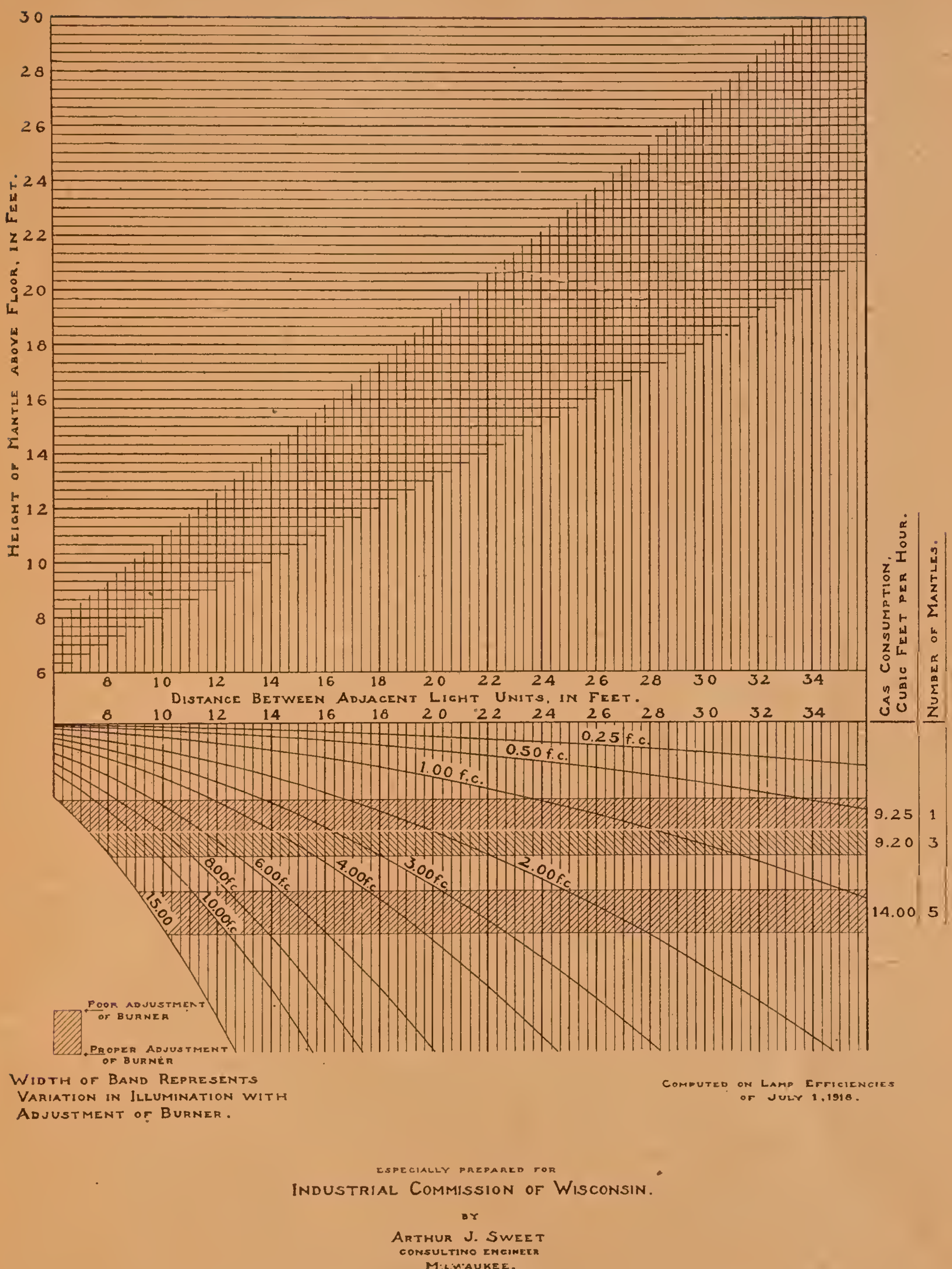


Plate II—Gas Lighting

Note: This chart refers to illumination on a horizontal plane 36 inches above the floor.

For determining the proper spacing and size of gas lamp to produce any desired intensity of illumination.

suspended at a considerable distance below the ceiling, the spacing should be determined with respect to the mounting height of the lamps.

Plates I and II are computed with reference to a horizontal plane 3 feet above the floor. The data is, however, sufficiently accurate for relatively small office interiors where the working plane is usually 2½ feet above the floor. It is also sufficiently accurate for large interiors when the working plane is at any lesser distance than 3 feet from the floor.

Size of Lamps.

The lower portions of Plates I and II present the data from which may be determined the size of lamp necessary to produce the specified intensity of illumination. Thus under the conditions of installation assumed in the above example, with lamps spaced 10 feet apart, let it now be assumed that the work is of such a character that, an illumination of 10 foot-candles is desired. Let it further be assumed that the incandescent electric lamp will be employed. Referring now to the lower portion of Plate I, the vertical line representing a 10 foot separation is followed to its intersection with the curved line representing 10 foot-candles. It is found that this occurs in the band representing the 150 watt lamp. This means that, if the more efficient types of reflector (Figs. 5, 11 and 12) be employed, the 150 watt lamp on 10 foot spacing will produce an average horizontal illumination of 10 foot-candles. If, however, the less efficient types of reflector (Figs. 7, 8, and 10) be employed, the 150 watt lamp will produce an illumination of about 8 foot-candles. Therefore, if it be desired to secure an illumination not less than 10 foot-candles and it is also desired to use one of the less efficient types of reflectors (Figs. 7, 8 and 10), it becomes necessary to use the next larger size of lamp, i. e. the 200 watt size.

The charts of Plates I and II allow a 30% factor for depreciation due to dirt on the reflector or lamp, or to deterioration of the filament or mantle in light giving power. With reasonable attention to maintenance, the lighting system can be maintained at a maximum depreciation not exceeding 30%. If, however, proper maintenance is not afforded, it will be necessary to employ larger lamps than those indicated by the charts.

It must be clearly realized that the charts of Plates I and II determine the size of lamp with reference to *horizontal* illumination. Order 2112, however, specifies the illumination *at the work.* If the work be chiefly on a horizontal plane, the charts may be directly used to determine the proper size of lamp with reasonable accuracy and exactness. If, however, the work be chiefly in some *vertical* plane, the problem of proper lamp size becomes much more complicated and can only be roughly determined by any general data. The ratio between the horizontal illumination and the vertical illumination depends chiefly on two factors,—(a) to what degree the light units are in front of the work, so that their light can illuminate the face of the work; and (b) the type of lighting unit employed. The first of these factors so depends upon local conditions that no general data of value can be given thereon. As for the second factor, the approximate ratio between the vertical and the horizontal illuminations are given for the various distinct types of reflectors in Table II. (Page 32.) These relations are necessarily approximate, since they vary considerably with varying conditions of installation. They vary but slightly, however, as between different makes of the same type of reflector.

Types of Lighting Units. (See also Figs. 15, 16, 19, 20 and 21).

It is only under most unusual conditions that the use of naked incandescent lamps will meet the requirements of good lighting and seldom will their use be permitted by the code. Therefore it becomes necessary to carefully select reflecting and diffusing accessories, which will modify the distribution of light from the lamps so as to secure reasonably uniform illumination on the working surfaces and surroundings, to reduce glare, to soften shadows, and to utilize the light economically.

For factory lighting there are at present five distinct types of reflectors (Figs. 5, 7, 8, 10, 11 and 12) which are especially worthy of consideration.

Special conditions sometimes make desirable the use of special types of reflectors, as for instance, the angle type of porcelain-enameled metal reflector or the concentrating prismatic and mirrored glass reflectors. The proper use of such

special types depends so largely on local conditions that no general data of value thereon can be given.

R. L. M. Standard Dome Reflector. (Fig. 5)

The R. L. M. Dome is a porcelain enameled reflector. The permanence of this material even under unfavorable atmospheric conditions, its moderate cost, and the ease with which it can be kept clean, make it highly useful for industrial purposes. The enamel coating must be dense so that as little light as possible will penetrate to the steel, since all light that reaches the steel backing is absorbed and therefore wasted. Enamels vary in efficiency; if of two reflectors one appears grayish or bluish in comparison with the other, it is sure to be considerably lower in efficiency.

The output of typical reflectors is 75 to 80 per cent of the light produced by the lamp. The eye is shielded from direct glare in a manner which will more than meet the requirements of Order 2113. The large area of the reflector tends to reduce the harshness of shadows, and the light distribution is such as to provide high illumination on vertical surfaces as well as on horizontal surfaces. (See Tables I and II.)

Clear bulb lamps should not be used with this reflector on mounting heights of less than 20 feet; bowl-frosting the lamps will usually be sufficient where protection against direct glare only is necessary, but where protection against reflected glare must be had, opal-glass caps or lamps with bowls enameled should be used. (Figs. 6 and 9.)

Deep Bowl Reflector—Porcelain Enameled. (Fig. 7)

The deep bowl of Fig. 7 also is a porcelain-enameled reflector. The output of typical reflectors is about 65 per cent of the light produced by the lamp. This reflector gives a maximum shielding of the lamp filament, but in no way modifies the brightness of the images of the lamp filament reflected from polished surfaces. Moreover the surface from which the light is received is so limited that shadows are sharp. Some diffusion of the light coming directly from the lamp can be attained by the use of bowl-frosted lamps, but this scarcely reduces reflected glare from polished surfaces adequately. Since opal-glass caps or bowl-enameled lamps would cause a very great loss of light if used with this reflector, the unit is

Fig. 5—R. L. M. Standard Dome.

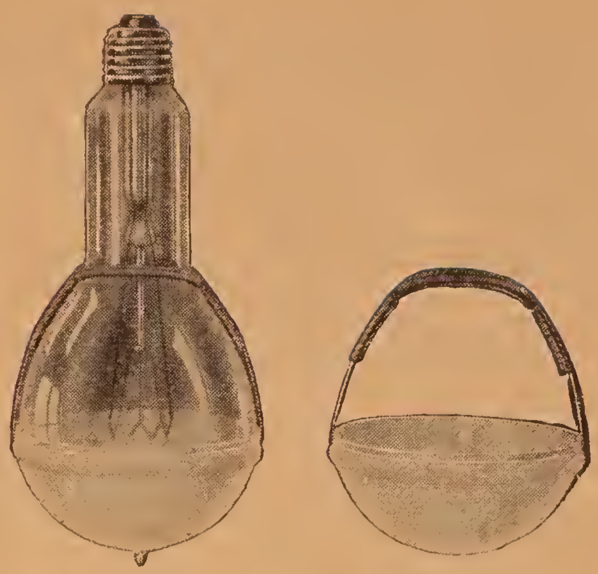


Fig. 6—Opal-Glass Cap.

Fig. 7—Deep Bowl Porcelain Enameled.

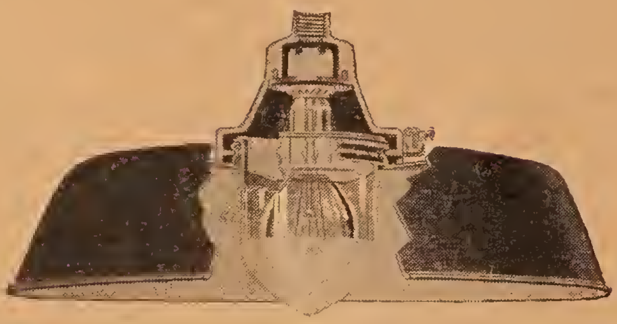


Fig. 8—Large Shallow Bowl. Lamp Fitted with Enlarged Opal-Glass Cover.

Fig. 9—Bowl Enameled Lamp.

Fig. 10—Large Shallow Bowl. Lamp Fitted with Polished Metal Cap.

out of the question where work is done on polished surfaces. The chief use for this reflector is for somewhat localized lighting over benches and tables.

Large Shallow-Bowl. Lamp Fitted with Enlarged Opal-Glass Cover. (Fig. 8)

This unit likewise is porcelain-enameled. The diameter of the reflector is very much greater than that of the R. L. M. Dome, running as high as 22 inches in the largest size available (for 300 watt lamp). The lamp is surrounded by a clear glass cylinder with the lower end rounded and enameled to reflect and diffuse the light. The area of the enameled portion is greater than that of an opal cap (Fig. 6), which together with the large surface of the reflector results in a very low brightness, making this unit highly desirable where softened shadows and the maximum freedom from reflected glare are important elements. The construction also prevents dust from settling on the lamp or within the cylinder, thus simplifying maintenance. The output is about the same as that of the deep bowl porcelain-enameled reflector.

Large Shallow-Bowl. Lamp Fitted with Polished Metal-Cap. (Fig. 10)

This unit is quite similar to the previously described one (Fig. 8). It differs in that a metal-cap is placed over the bowl of the lamp. This cap intercepts and reflects the light against the porcelain-enameled surface, where it is thoroughly diffused and directed to the work. The output is approximately the same as for the deep bowl porcelain-enameled reflector. The unit has the disadvantage of a cap which deteriorates in time, and requires renewing.

Mirrored Glass Reflector—Deep Bowl. (Fig. 11)

This type of reflector is made of clear glass blown in the shape of a reflector, on the exterior surface of which a thin layer of silver is coated and this in turn covered by a protective enamel. To eliminate the brilliant images of the lamp filament, or striations, which would appear on the surface illuminated, the reflector surface is corrugated.

Such mirror reflectors are highly efficient, in typical reflectors having an output as high as 85 per cent of the light pro-

duced by the lamp, because the light passes through clear glass to a silver surface, one of the best reflecting surfaces known, and therefore find wide application for both direct and indirect illumination in factories and offices. They are made in the deep-bowl shape for industrial lighting purposes, and their use is limited in the same manner as the deep-bowl porcelain-enameled reflector. Special concentrated mirrored glass reflectors are very effective in the lighting of high interiors such as monitors. Because of the corrugations more labor is required to keep these reflectors clean.

Prismatic Glass Reflector—Deep Bowl. (Fig. 12)

This type of reflector is made of clear glass with many small prisms composing the entire body of the reflector. The principle involved is that of total reflection from properly designed prisms. Since the light is reflected by clear glass only, the absorption is low and the efficiency of these reflectors very high, typical reflectors having an output as high as 75 per cent of the light produced by the lamp. They are made in the deep-bowl shape for industrial lighting purposes. Since 15 to 20 per cent of the light is transmitted above the horizontal, these reflectors brighten the ceilings and walls, thereby giving the room a cheerful appearance and somewhat softening shadows. As in the case of mirrored glass reflectors a strongly concentrated light distribution is obtainable for use in high interiors. The distribution of light from the reflector, illustrated in Fig. 12, produces a higher illumination on vertical surfaces than is obtainable with any other type of reflector available at present. More labor is required to keep these reflectors clean than in the case of reflectors with a smooth surface. Unless bowl-frosted lamps are used, these reflectors should not be used where the work is on polished surfaces.

Choice of Reflector.

From Plate 1 it is apparent that the type of reflector used with electric incandescent lamps affects the size of lamp required because of the difference in efficiency of the various reflectors. But the type of reflector to be used cannot be decided on the efficiency basis alone. Other important factors are the appearance that the lighted room makes, the amount of direct glare and reflected glare, the character of the shad-

ows, and the ease of maintenance. In Table I, the five types of industrial units are rated with respect to these seven requirements. All of these items should be carefully considered when the type of reflector is chosen for any room or space. The importance of the various qualities is different for different purposes. Thus in an aluminum utensil manufacturing plant, the elimination of reflected glare is of first importance, whereas in a packing and shipping room it is of slight importance.

The approximate ratio between the vertical and the horizontal illumination produced by the various reflectors is given in Table II. (See also Page 23).

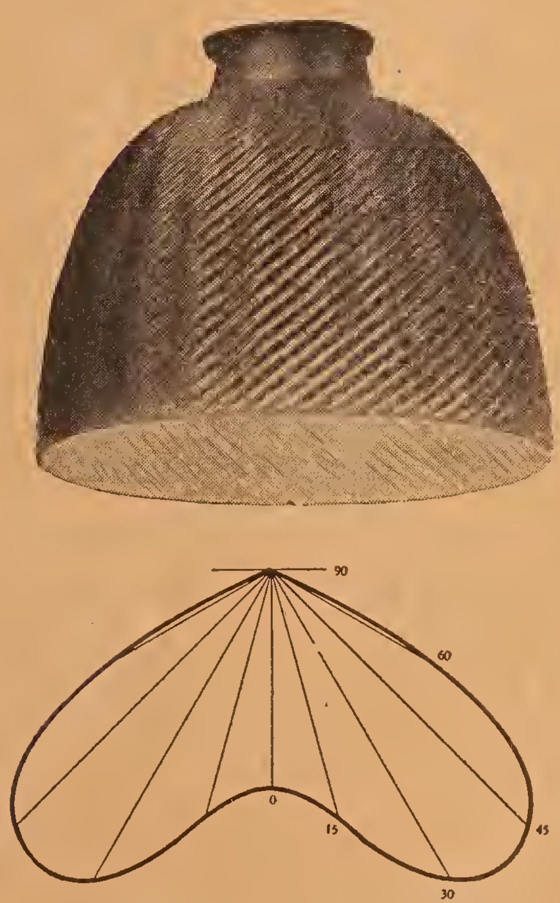


Fig. 11—Mirrored Glass Reflector—Deep Bowl.

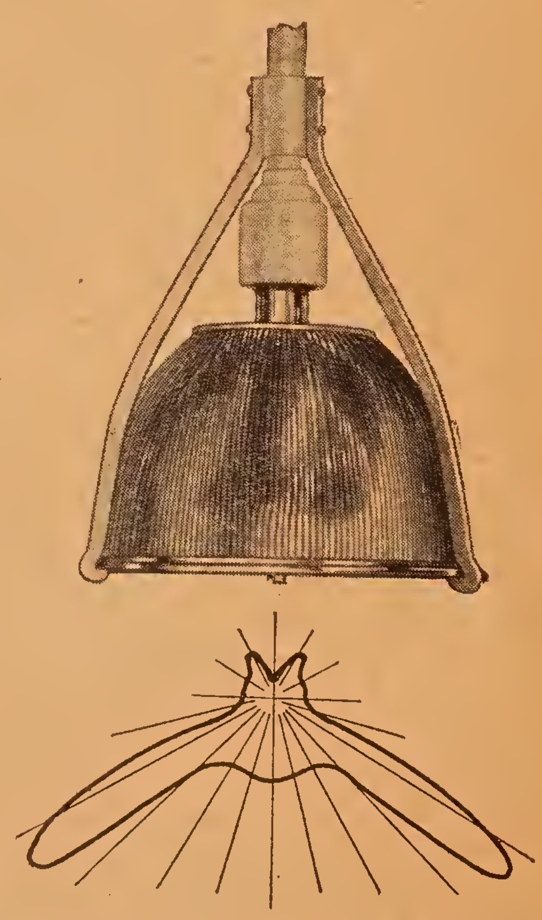


Fig. 12—Prismatic Glass Reflector—Deep Bowl.

TABLE I.—RATING OF REFLECTORS ACCORDING TO QUALITIES

Qualities	Metal, Porcelain-Enameled						Mirrored Glass		Prismatic Glass	
	R. L. M. Standard Dome Fig. 5 Clear Lamp	R. L. M. Standard Dome Fig. 5 Bowl-Frosted Lamp	R. L. M. Standard Dome Fig. 5 Bowl-Enameled Lamp	Deep Bowl Fig. 7 Clear Lamp	Deep Bowl Fig. 7 Bowl-Frosted Lamp	Large Shallow Bowl Lamp Fitted with cap Fig. 8 and 10	Deep Bowl Fig. 11 Clear Lamp	Deep Bowl Fig. 11 Bowl-Frosted Lamp	Deep Bowl Fig. 12 Clear Lamp	Deep Bowl Fig. 12 Bowl-Frosted Lamp
Horizontal Illumination	Best	Excellent	Very good	Very good	Good	Good	Excellent	Very good	Excellent	Very good
Vertical Illumination	Best	Excellent	Very good	Good	Good	Good	Very good	Very good	Best	Best
Favorable Appearance of Lighted Room	Fair	Good	Good	Poor	Poor	Good	Poor	Poor	Very good	Very good
Direct Glare	Poor	Good	Excellent	Fair	Good	Excellent	Fair	Good	Fair	Good
Reflected Glare	Condemned	Poor	Good	Condemned	Poor	Very good	Condemned	Poor	Condemned	Poor
Shadows	Fair	Good	Excellent	Poor	Fair	Best	Poor	Fair	Fair	Good
Maintenance	Best	Very good	Fair	Excellent	Very good	Fair	Excellent	Very good	Good	Fair

Note: The grades assigned to the different units are only relative. A rating of poor does not mean that the unit is so poor that it should not be used. It merely means that in respect to the particular quality in question, it is poor relative to the others. Moreover the ratings apply only when the various units are used with the same size of lamp and under similar conditions. A unit condemned with respect to a specific quality should not be used if the particular quality is of first importance. If the particular quality is of but slight importance, the unit may be used with the expectation of satisfactory service.

Favorable appearance of lighted room refers only to the general casual effect produced by the complete system, and is not intended to rate the unit as to its satisfaction from the standpoint of good vision or freedom from eye fatigue.

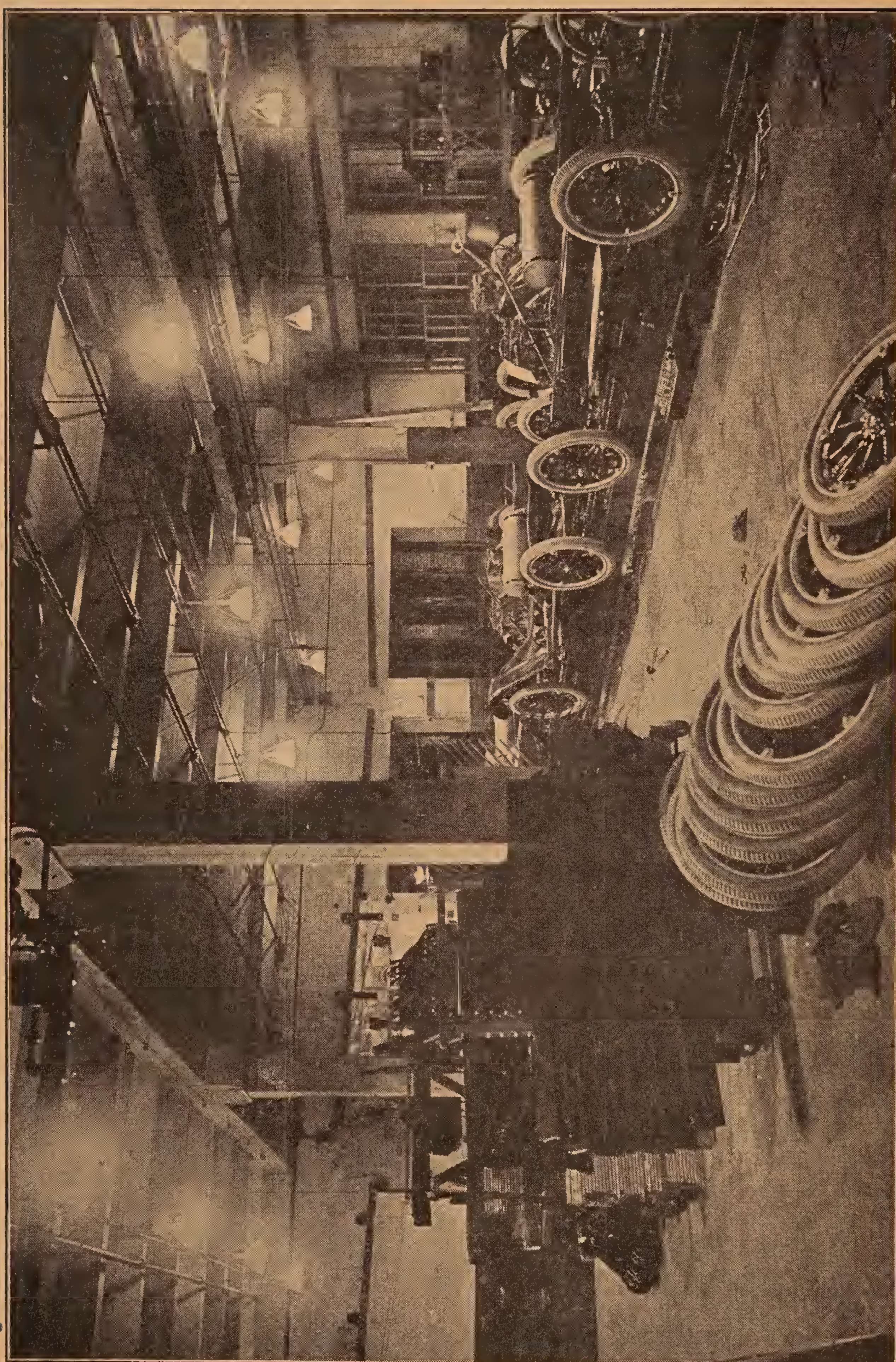


Fig. 13—In this assembly room an intensity of 15 foot-candles on the horizontal plane at the level of the chassais is provided. This is five times as much as the code demands, but it enables production to go along at the usual rate even after the daylight is gone.

Fig. 14—Knitting room of a hosiery mill, in which lighting units of the type illustrated in Fig. 8 are used. Illumination is 10 foot-candles on 36 inch horizontal plane and 5 foot-candles on vertical plane at same elevation. It is an excellent installation. The small lamps at the ceiling are the emergency lights called for by Order 2116.

TABLE II—APPROXIMATE RATIO BETWEEN THE VERTICAL AND THE HORIZONTAL ILLUMINATION

Type of Reflector	Vertical Illumination in per cent of Horizontal Illumination	Correction Factor to be applied to size of lamp when Plate I is used for vertical illumination determination
Deep-bowl prismatic-glass reflector Special Industrial unit, Fig. 12	55%	1.82
R. L. M. Standard Dome porcelain-enameled metal reflector, Fig. 5	50%	2.00
Deep-bowl mirrored-glass reflector, Fig 11	45%	2.23
Large shallow-bowl porcelain-enameled reflector—lamp fitted with shield or cap, of metal or opal glass, Figs. 8 and 10	45%	2.23
Deep-bowl porcelain-enameled metal reflector, Fig. 7	45%	2.23

Note:—"Horizontal illumination" refers, of course, to the illumination produced on a horizontal plane. In like manner, "vertical illumination" refers to the illumination produced on a vertical plane.

In using this table, first obtain the proper spacing and size of lamp from Plate I; then to get correct lamp size to give the desired intensity of illumination on vertical surfaces multiply by the "correction factor" above.

Indirect Lighting. (Figs. 15 and 16)

All of the foregoing discussion and data pertains to direct lighting in industrial service. During recent years, however, there has been a growing tendency to employ indirect lighting for certain classes of work in the textile industry. Wisconsin industries were pioneers in this movement. The advantages are the complete elimination of direct glare, the almost complete elimination of reflected glare, the very good appearance of the lighted room, the elimination of objectionable shadows and indeed the almost complete elimination of shadows. The disadvantages are poor efficiency and more expense for maintenance. The conclusion must not be drawn, however, that indirect lighting is ideal for all classes of service. Illumination of too diffuse a character is undesirable where a directed light is needed as for manufacturing where the work is on surfaces in many planes.

Indirect Lighting Computations.

Proper spacing of indirect units may be easily determined as follows: Subtract 3 feet from ceiling height of the room;

multiply the result by 1.8 to determine the best spacing; or multiply by 2.4 to determine the widest permissible spacing. In general, sufficiently satisfactory results will be obtained if the spacing does not exceed twice the value obtained by subtracting 3 feet from the ceiling height. For the same size of lamp indirect lighting units will produce about 60 per cent the illumination on a 36 inch horizontal plane secured with the R. L. M. Standard Dome porcelain-enameled reflector, provided the ceiling finish is white.

By comparison of the above rule with the data presented in Plates I and II, it will be noted that light units may be spaced considerably further apart when indirect lighting is employed than when direct lighting is employed. This results in the use of fewer light units; so that while the cost of one indirect unit is greater than that of one direct unit, the total cost of installation is usually approximately the same.

Indirect units should be mounted at such distance below the ceiling that the entire ceiling is lighted to an approximately uniform degree. Figures 15 and 16 illustrate two commonly used types of indirect fixtures.

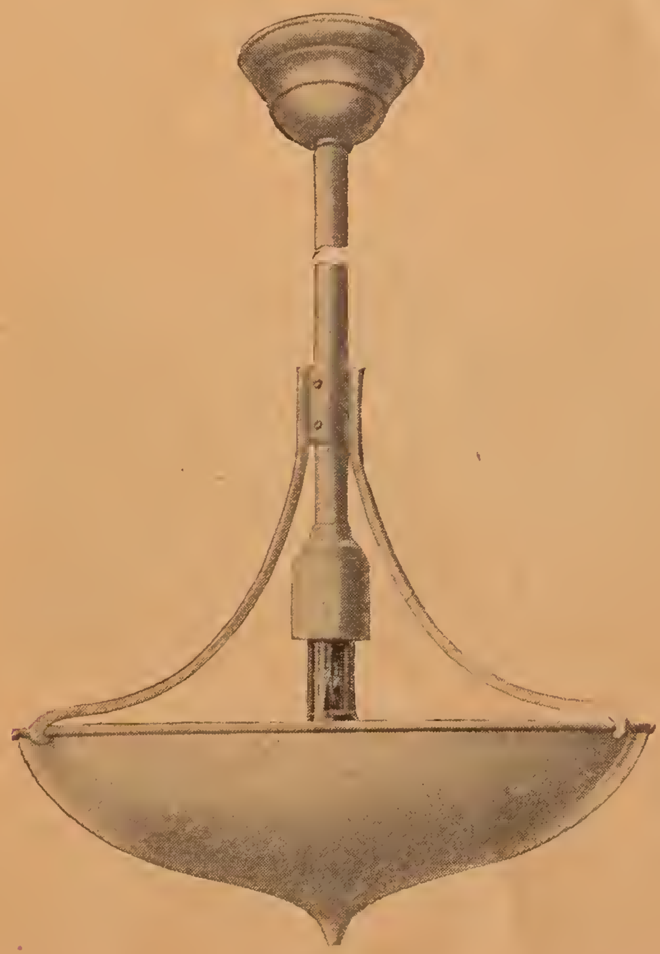


Fig. 15.—Porcelain-enameled bowl type of indirect fixture. Bowl itself acts as reflector.

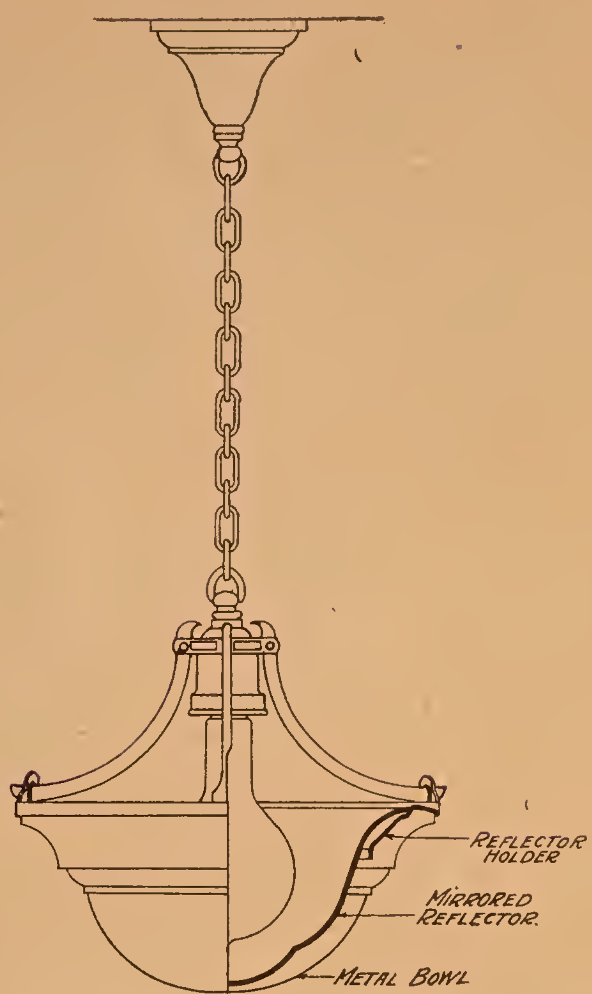


Fig. 16.—Indirect fixture provided with auxiliary mirrored glass reflector.

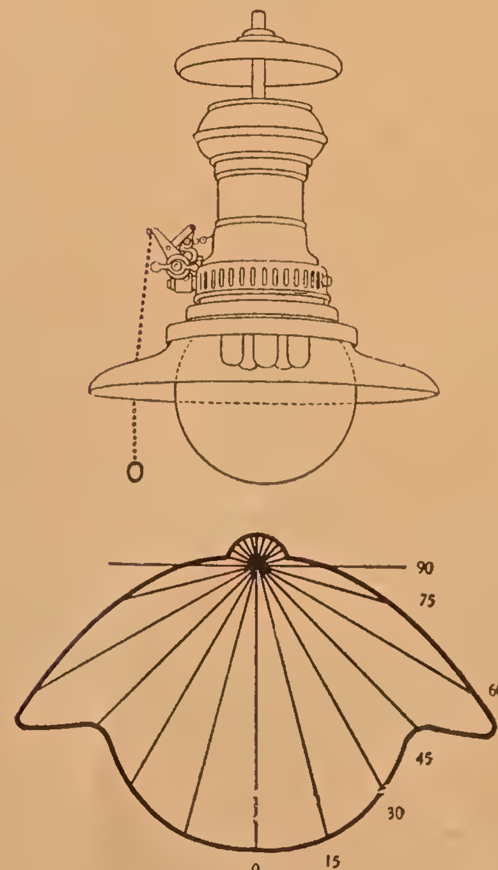


Fig. 17.—Five mantle gas lamp

Local Lighting.

As previously stated local lighting solely is not permitted by this code, and in any event is undesirable and is therefore to be avoided if possible. Local lighting is always objectionable because of the sharp contrasts in intensity which are inherent with the system; because small and inefficient lamps must be used which are of a size adopted for use in the home and therefore are subject to theft; because it is difficult to keep them properly adjusted in the reflectors. Maintenance of local lighting systems is known to be high; reflectors and lamps are very much more rapidly soiled than with overhead lighting; lamps are broken and reflectors bent or totally discarded; workmen substitute larger lamps than the reflectors will properly provide shading for; the local light of one workman is likely to be adjusted so as to shine in another man's face.

There are, however, some instances in which an operation requires some supplementary local illumination. No general procedure for calculating the size and location of units can be formulated because of the many different conditions encountered. It is seldom necessary to use lamps larger than 50 watts, and smaller lamps usually will be adequate. It is difficult and costly, for instance, to illuminate stitching operations with

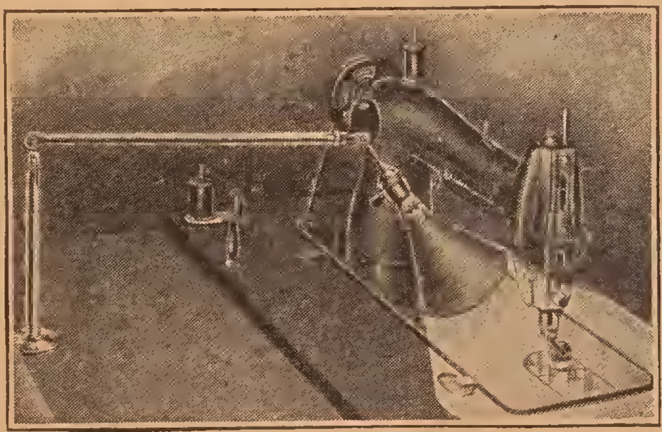


Fig. 18—Adjustable Fixture for Local Lighting of Stitching Operations.

overhead lighting only. Here a local unit of 15 watt size (Fig. 18) supplements the overhead lighting. Notice that a fixture is used which keeps the light adjusted to the proper position. Flexible drop cords are incapable of doing this.

Gas lighting (Fig. 17)

The use of gas lighting has formerly been handicapped by lack of adaptability, difficulty of maintenance, and poor planning. Recent developments in efficient mantle gas units, equipped with well designed reflectors, are worthy of consideration. The installation cost of a first-class mantle gas and of a first-class electric installation are approximately the same; operating costs vary in different localities, depending on the price of gas and electric current. The reliability of gas service has encouraged its use for emergency lights. As will be noted from Plate II, three sizes of gas mantle lamps are available: single mantle, three mantle and five mantle.

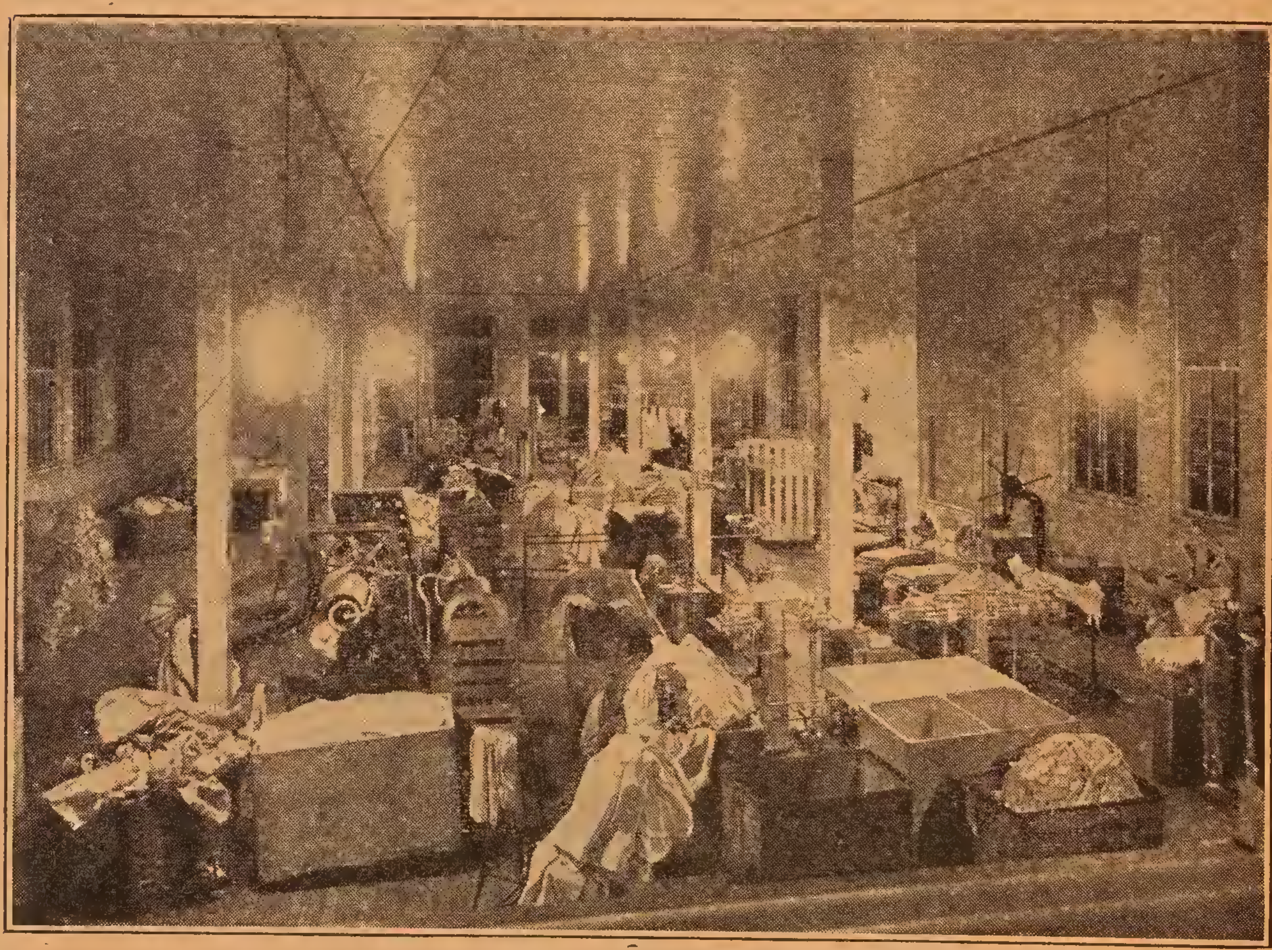


Fig. 19—Laundry illuminated by five mantle gas arcs. (*See also Fig. 17.*)

Mercury Vapor Lamps. (Fig. 20)

The use of mercury vapor lamps has already been suggested. This lamp consists of a glass tube one inch in diameter and from twenty to fifty inches long. One end of the tube, enlarged into a bulb (Fig. 20) for holding metallic mercury, and a small metal cup at the other end serve as electrodes or carriers to the electric current, which is supplied to them through

lead in wires sealed into the glass. The tube contains no air or other gas, so that when an electric current is caused to pass from one electrode to the other, it vaporizes a small quantity of the mercury, which fills the tube. The vapor is rendered luminous by the passage of the current, thereby giving forth light of a peculiar peacock-blue color. The lamp gives off mainly yellow-green and blue rays. In addition to the tube, a commercial type of mercury-vapor lamp consists of the necessary electrical accessories for starting the flow of current, when the lamp is turned on, and maintaining it in steady operation.

Fig. 20—Mercury vapor lamp.

The peculiar color composition of the light gives it distinct value for industrial purposes.

(1) It enables the eye to see small objects and fine detail with great sharpness.

(2) It enables the eye to see distinctly with low illumination, because of this sharpness of vision, thereby rendering objects in shadows visible.

(3) It is easy on the eyes because of the low brightness of the tube (14.9 candle-power per square inch). This brightness, although well within the maximum permissible for overhead lighting, under the conditions of Order 2113, nevertheless may cause fatigue, when lamps are installed at low elevations and not shaded properly.*

(4) Shadows are softened.

(5) Because of the low brightness of the tube, images of the lamp in polished surfaces are much less harmful than for most other types of lamps, which have not been well shaded in all downward directions.

As previously stated, calculations for installations employing these lamps will not be given here. Factory managers in-

terested may get advice from consulting engineers or the manufacturers of the lamp. Their correct use requires intimate knowledge of the lamp and its construction, which makes it impossible to give instructions for their use in a bulletin of this type.

Yard Lighting. (Fig. 26)

Although the illumination required in yards is of a much lower order of intensity, the same general principles apply as for interior lighting. In general lamps may be installed farther apart than for interior lighting, by using special widely distributing reflectors, but care must be exercised that the illumination at any point is secured from more than one direction, otherwise there may be deep shadows cast, where there ought to be light to reveal danger points. This sets certain limitations upon the area it is desirable to attempt to illuminate from a single source. Yard lighting lamps should be mounted at least 20 feet above the ground level, higher if possible, to shorten the shadows and minimize glare. If the lamps must be installed lower than 20 feet, lamps larger than 100 watts should not be used. R. L. M. Standard Dome porcelain-enameled reflectors, Fig. 5, of the weatherproof type, may be used to good effect, but the spacing between units should not exceed four times the height above the ground. Prismatic refractor units, Fig. 21, permit a spacing between units of eight times the height above the ground.

Shading of Lamps for Overhead Lighting. The provisions of Order 2113 can best be illustrated by the diagram of Fig. 22. The most distant light source, from the workman, is shown at A. It is elevated 6′ 0″ above eye-level, which is less than one-fourth the distance from the eye, 53 feet. This lamp then must be shaded as specified in the order. If it were elevated to position B, which is 13′ 3″ above eye-level, it would not require shading to comply with this order.

In large interiors with low ceilings, it is not possible to elevate lamps so as not to require shading. It then becomes necessary to use a reflector that screens off all direct view of the luminous element (tungsten filament or gas mantle) in the limiting angle of 14 degrees below the horizontal. All well designed dome reflectors provide a screening angle greater

than 14 degrees; whereas the deep-bowl types provide a still greater screening angle (in some cases 30 degrees). Almost any of the commonly used types of reflecting glassware, such as prismatic glass and opalescent glass, will reduce the brightness of the light source to that specified in the order, and the opaque reflecting media, porcelain-enameled steel and mirrored glass, completely screen the light source.

While the use of proper reflectors or other suitable acces-

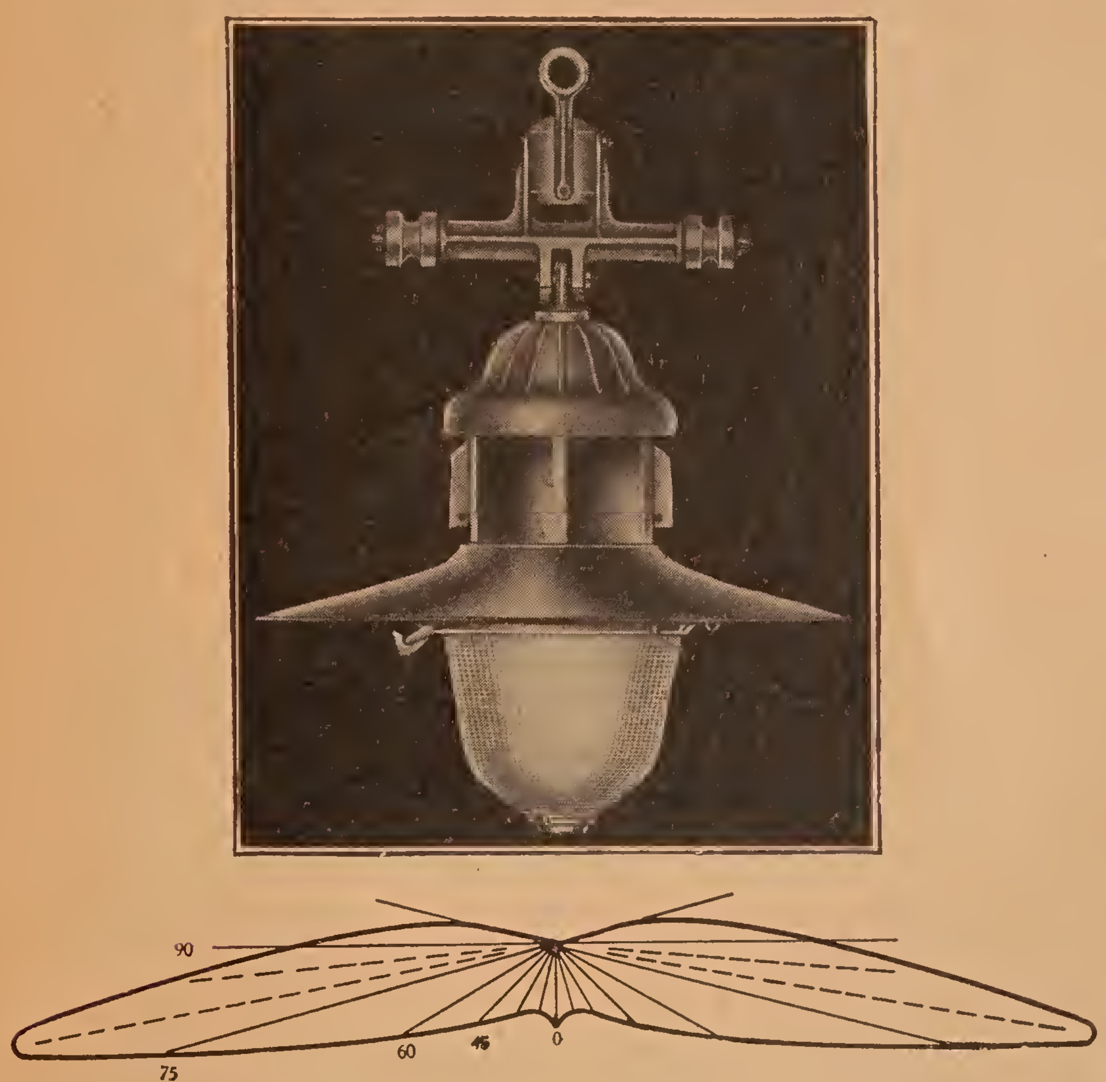


Fig. 21—Prismatic refractor yard lighting fixture permits broadest spacing of lamps.

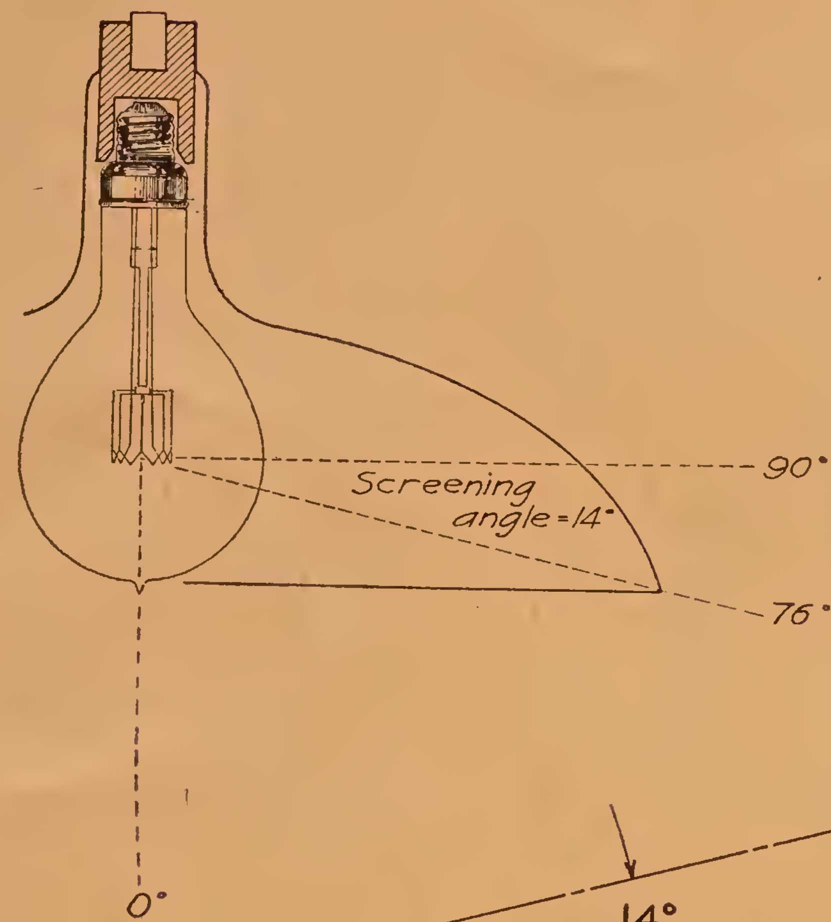
sories is made mandatory under certain conditions, they should be used, even where not required by the code, for economy sake. With a well designed and efficient reflector, the illumination at the work may be increased as much as 60 per cent over what the bare lamp will provide.

Where the principal work is done on polished surfaces, images of the lamp in these surfaces prove nearly as distressing as the lamps themselves, and are much more difficult to

If the most distant light source from the eye is installed at A, its elevation above eye-level is less than one-fourth its distance from the eye. The lamp then must be shaded by means of a reflector having a screening angle of at least 14 degrees. Moreover, if the reflector is of glass, it must be sufficiently dense to reduce the brightness, of the brightest square-inch of reflector surface, to the prescribed limit of 75 candle-power.

A reflector with a 14 degree screening angle similar to the illustration to the left, cuts off all direct view of the lamp, for all positions beyond a radius of 24 feet from the lamp. At distances less than 24 feet, the ratio of elevation to distance exceeds one-fourth.

If the lamp is located at B, it need not be shaded for then its elevation is one-fourth its distance from the eye. However, economy in the use of light, makes the use of a reflector desirable under this condition as well.



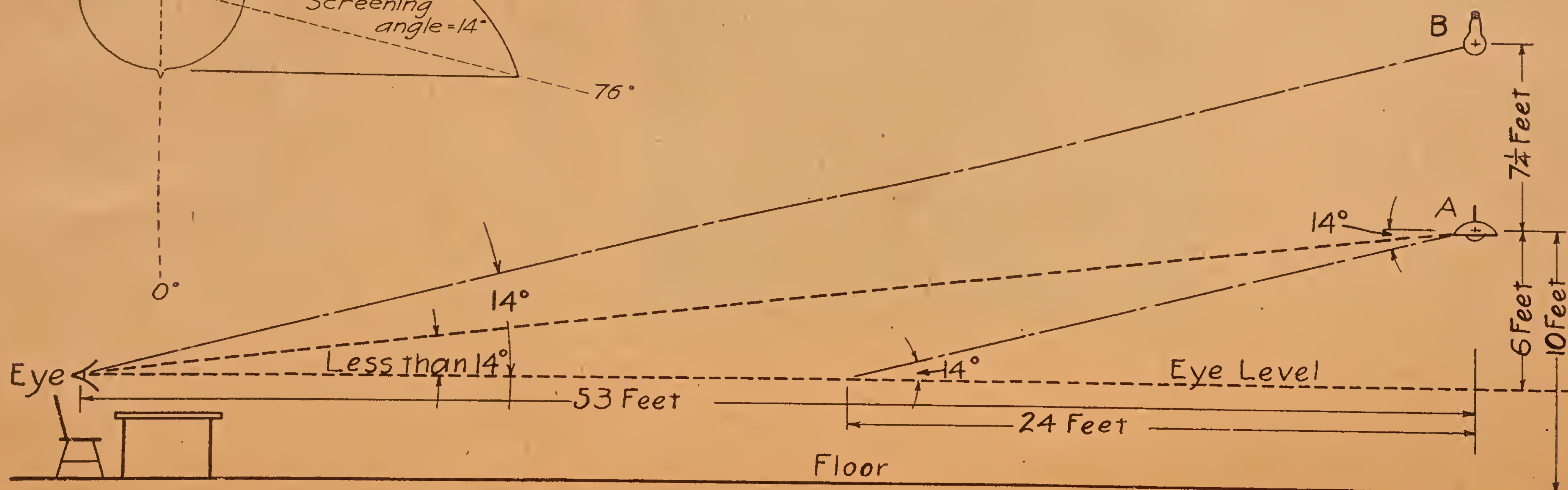


Fig. 22—This diagram illustrates the provisions of Order 2113, Shading of Lamps for Overhead Lighting.
Note: The reflector contour shown above does not indicate a preference on the part of the Industrial commission. Other contours providing the same minimum screening angle will conform to the requirements of this order.

avoid. In such circumstances the brightness of lamps in all downward directions should be reduced. In some cases bowl-frosting the lamps may suffice, whereas in other instances the use of bowl-enameled lamps, metal caps, dense enclosing glass globes, mercury-vapor lamps, or indirect lighting may be needed in order to produce satisfactory results. (See discussion of types of lighting units page 23.)

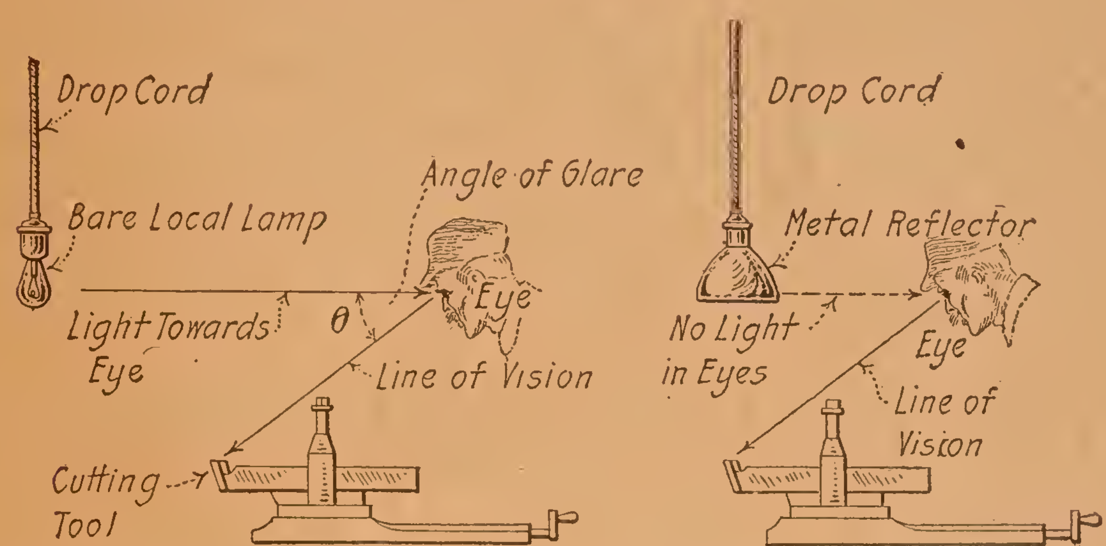


Fig. 23—Illustrating the shading of local lamps as required by Order 2114.

Fig. 24—Illustrating the ill-effects of exposed local lamps in one case, and the advantages of shading lamps in the other.

Shading of Lamps for Local Lighting. Order 2114 forbids the use of exposed local lamps. Such lamps must be equipped with opaque reflectors or translucent reflectors, shades or globes which limit the brightness as specified in the order (three candle-power per square inch). Metal reflectors are preferable, since they are not subject to breakage.

The requirements of this order may best be illustrated by Figs. 23 and 24. The bare local lamp to the left of Fig. 23 is a constant source of glare, which is very injurious to the workman's eye, and is prohibited by the order. To the right, the lamp is equipped with a suitable reflector and the provisions of the order are complied with. To the right, in Fig. 24, the man is working at a lathe illuminated by an exposed lamp. More light shines in his eyes directly, than on the work, making seeing very difficult and causing ocular discomfort. To the left, the same work is done with a well-shaded lamp, as required by the orders. Now a much more powerful light is directed to the work and no light from the lamp enters the eye directly, greatly increasing the comfort of the man and improving vision.

While this order requires the use of reflectors or shades with local lamps, this again is to the advantage of the employer, from the economy standpoint. The reflector intensifies the light directed to the work, which means that smaller lamps may be used. Not only are the workman's eyes protected, but the stray light, which causes the glare, is caught up by the reflector and utilized where wanted, *at the work*. In Fig. 25 four types of metal reflectors for local lighting are shown. The angle types should be used for lighting vertical surfaces, but should always be fixed and in such position that a direct view of the lamp is impossible from any working position in the shop. The lighting of horizontal surfaces and many machine operations may be accomplished by means of the cone or bowl type of reflectors.

As already pointed out local lamps should not be used except where nothing else will serve the purpose. The operations in any factory or mill, which cannot be illuminated by means of overhead lighting, are few indeed. When it is considered that a moderate intensity of illumination from an overhead system is required in all factories, it becomes a better plan to intensify the overhead lighting so that the illumination received at the work corresponds to ordinary practice as given in Order 2112, rather than install a system of local lamps. When local lighting must be used for a given operation, it should be supplementary to the general illumination. In other words its functions should be merely to intensify the illumination at the

work, or to give light in a particular direction, as may be required.

Distribution of Light on the Work. The provisions of Order 2115 make mandatory a reasonably uniform distribution of light on the work, and the application has been fully discussed under spacing and mounting of lamps.

Emergency Lighting. The spirit of Order 2116 requires that the emergency lighting system be kept entirely separate and distinct from the general lighting system. The emergency lighting system is designed to provide illumination sufficient for the employes to get out of the building under any and all conditions liable to occur, even when the regular lighting system has been rendered useless. Hence it is imperative that the

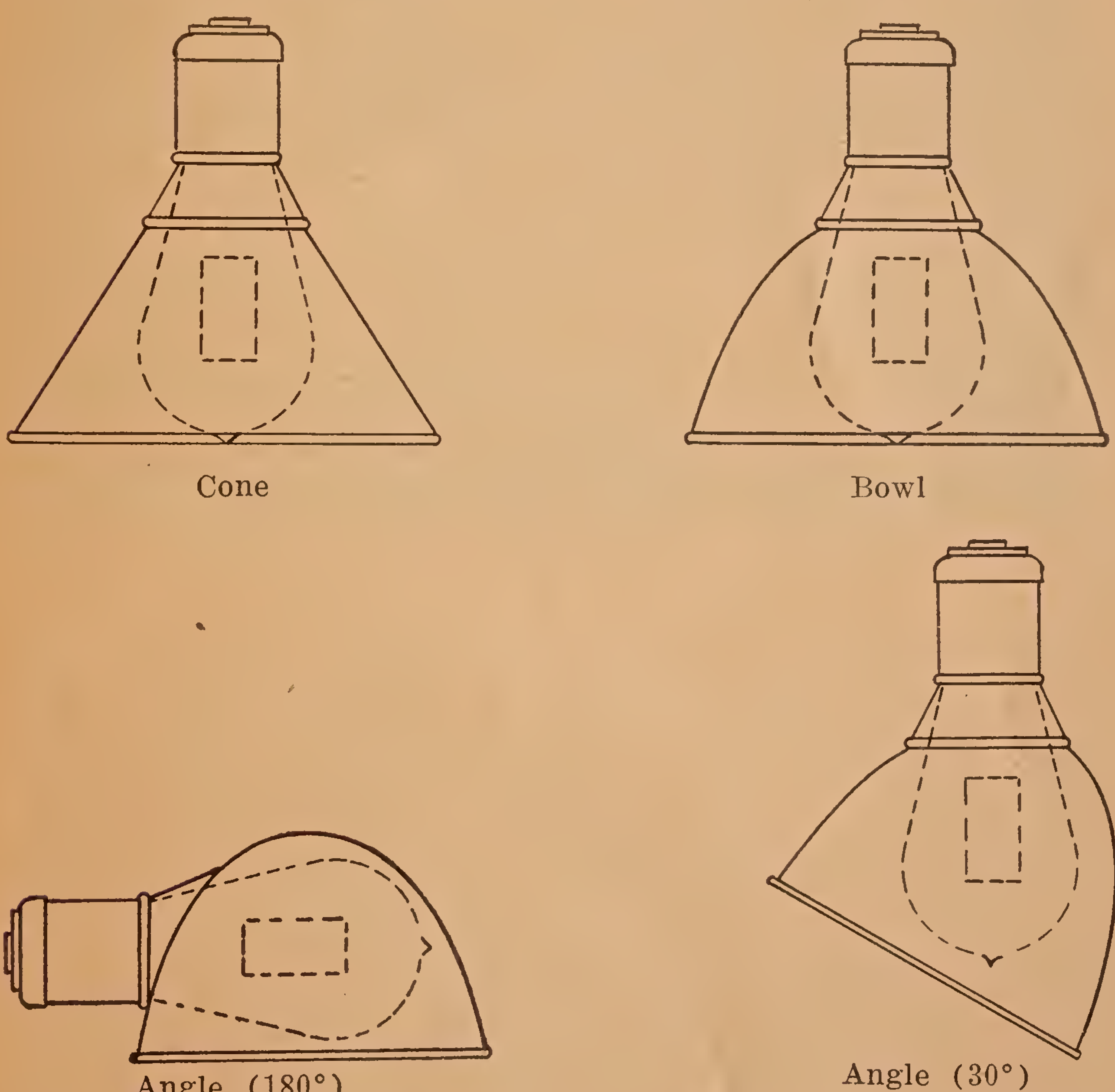


Fig. 25—Local lighting reflectors which adequately shade the lamps. Ordinarily metal reflectors are preferred, because they are non-breakable. If glass reflectors are used they must be dense enough to reduce the brightness of the brightest square inch of reflector surface, to three candle-power, as specified in Order 2114.

emergency lighting be made as reliable as is humanly possible. This means that the system should be installed in a first class manner and so maintained. To this end the emergency system should be frequently inspected and the necessary renewals of parts and repairs made.

Fig. 26—Example of Proper Yard Lighting.

Electric Emergency service should, when possible, be taken from mains that have no connection with those supplying the regular lighting system. In the case of factories supplied with central station service, the emergency system should be supplied from mains from a separate station, sub-station or transformer; whereas factories supplied with isolated plant service should arrange for (1) central station service for the emergency system, (2) service from another isolated plant, (3) service from a storage battery, or (4) service from a separate generating unit driven by a separate prime mover.

In the case of factories supplied with electrical energy from central stations, it may be impossible to get emergency service from a separate main. Under this condition it becomes neces-

sary to take the emergency service from the same main as the regular lighting system service, but the emergency system must be supplied from a separate service cabinet, connected to the main service to building ahead of the main service fuses, and it is good practice to make the size of this emergency system several times heavier than required and fused accordingly, so that the emergency system is not likely to be rendered useless by the blowing of fuses.

Gas Lamps provide a very satisfactory means of emergency lighting, where gas service is available.

Switching and Controlling Apparatus. Order 2117, as explained in the note accompanying it, requires the installation of properly labeled (or identified by position) switches or control apparatus, which will enable the night watchman or other qualified persons to turn on enough lamps in any part of the premises to enable them to see their way around with safety, thereby making the use of lanterns and flashlights unnecessary. These switches, preferably, should be installed at the points of entrance to the various sections. Sometimes several points of control are desirable.

Maintenance. Order 2118 requires systematic maintenance of the natural and artificial lighting equipment.

In time factory and mill windows become covered with dirt and produce greatly decreased natural light in consequence. These losses may easily be great enough to affect the workmen seriously, and to necessitate the use of artificial light at times when otherwise it would not be required. Regular window cleaning should therefore be a part of the routine of every factory and mill building or group of buildings.

Lighting installations are designed to give desirable initial illumination intensities at the work, but if the illumination is to continue satisfactorily, adequate maintenance must be instituted. In time lamps, globes, and reflectors become covered with dust, the lamp bulbs become black and burn out, reflectors are cracked and injured, and the electric wiring may become defective. Due to all these causes the illumination in the shop deteriorates to the point where complaints may come in from employes. The losses of time from such circumstances, when added up throughout the year are more than likely to exceed the expense of systematic attention to such items in advance.

How to Make Lighting Measurements.

Since the intensities of illumination required by the code are specified in foot-candles at the work, an instrument must be available for measuring intensity of illumination at any point desired. The foot-candle meter, Figs. 27 and 28, is a compact, completely self-contained and inexpensive instrument and designed especially for this purpose. It weighs about three pounds and measures $7\frac{7}{8} \times 6 \times 1\frac{1}{2}$ inches. The various parts are shown in Fig. 28. Once calibrated, the instrument may be used over long periods without further attention except for occasional renewal of the standard dry cell.

To make a foot-candle measurement, the voltmeter is set at the designated line by adjusting the rheostat, which is in series with the dry cell and standard lamp in the light box. Then note the point at which the brightness of the translucent spots, lighted by the standard lamp inside the light box, equals that of the illuminated background, which receives the intensity it is desired to measure. In Fig. 29 the foot-candle meter screen is shown as it appears under a given intensity of illumination. The spots near the right end of the screen are brighter than the background; those at the left are darker than the background. However, somewhere between there is a changing point, from bright to dark, at which the brightness of the spots is the same as the brightness of the background. In the case illustrated, this point is at 5.5 foot-candles.

Since it is not necessary to manipulate any parts of the instrument, where the volt-meter has once been properly set, it is possible to walk about rapidly noting the manner in which the intensity of illumination changes at the various working positions. No knowledge of the principles involved in the foot-candle meter are necessary in order to operate it successfully. Anyone can be taught to make accurate readings with this instrument in ten minutes of instruction.

Every electrical contractor should have such an instrument and every electrical department of industrial plants should be possessed of one. This instrument is as essential to the man engaged in the design, installation and maintenance of lighting as the voltmeter is to the successful operation of an electric power station. Without a foot-candle meter, we are doing guess work; with it we can determine quantitatively the lighting conditions in a room.

Fig. 27—Foot-Candle Meter.

Fig. 28—Interior view of Foot-Candle Meter.

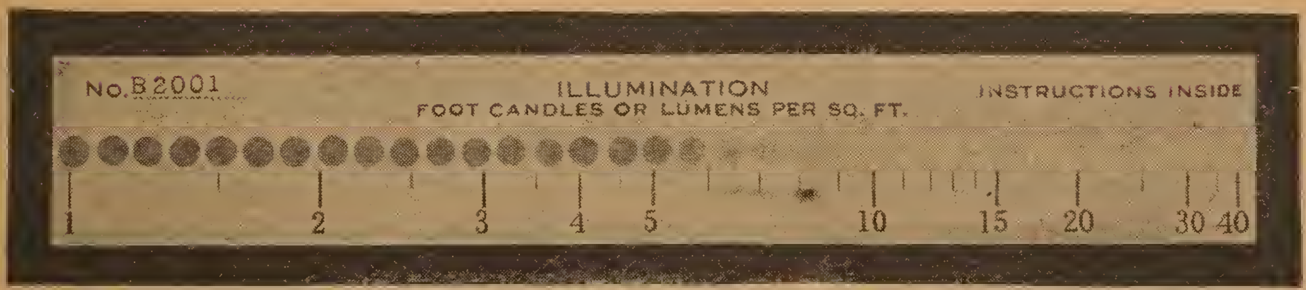
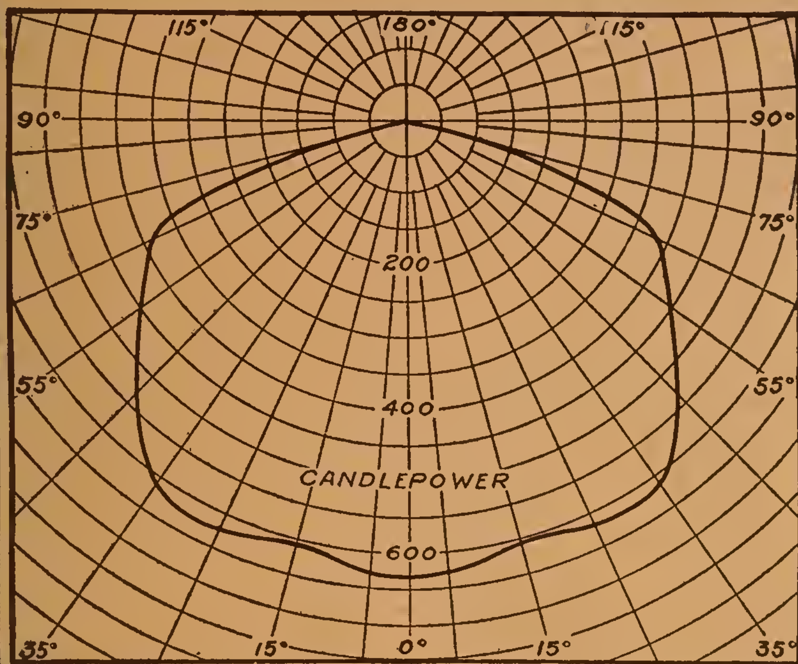


Fig. 29—Foot-Candle Meter Screen Indicating 5.5 Foot-Candles.

The candle-power of the brightest square inch of light source as specified in Orders 2113 and 2114 of the code may be measured by means of the foot-candle meter. An opaque board, with a square or circular hole one square inch in area, is placed against the surface of the light source in such position that the brightest spot emits light through the hole in the board. The board must be of such size as to prevent any other light from the source to strike the foot-candle meter. The foot-candle meter is then placed at some convenient distance from the unit and read, care being exercised to exclude all light from the instrument except that emitted from the hole. If the instrument is read at a position one foot distant from the light source, the foot-candles observed will also be the candle-power; if the photometer is two feet distant, the foot-candles observed must be multiplied by four to obtain the candle-power; if three feet, they must be multiplied by nine, etc., in accordance with the law of inverse squares.

Light Distribution Curves.

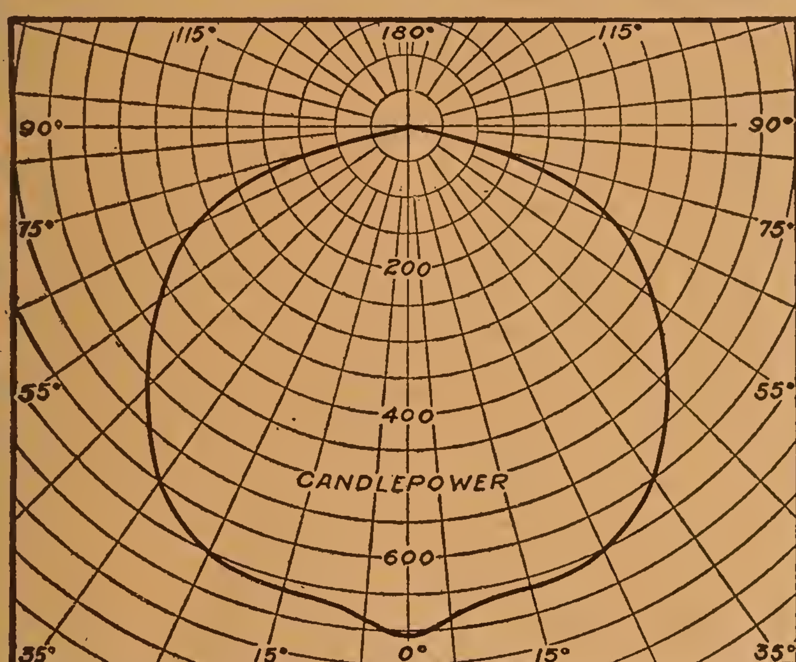
For the use of illuminating engineers who desire to know the exact performance of the five distinct types of reflectors (Figs. 5, 7, 8, 10, 11 and 12) previously described, light distribution curves are given herewith. These curves show the candlepower at the various angles and the appended tables give the lumens delivered in the important zones.



Porcelain-Enameled RLM Dome

Clear Lamp

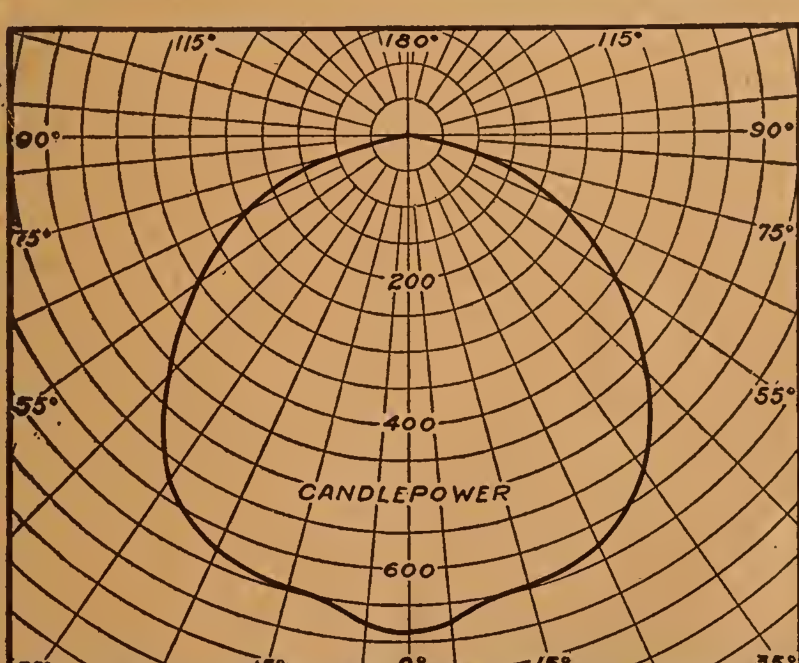
Zone	Lumens	% Total Clear Lamp
0°-60°	1695	58
0°-90°	2220	76



Porcelain-Enameled RLM Dome

Bowl Frosted Lamp

Zone	Lumens	% Total Clear Lamp
0°-60°	1695	58
0°-90°	2130	73

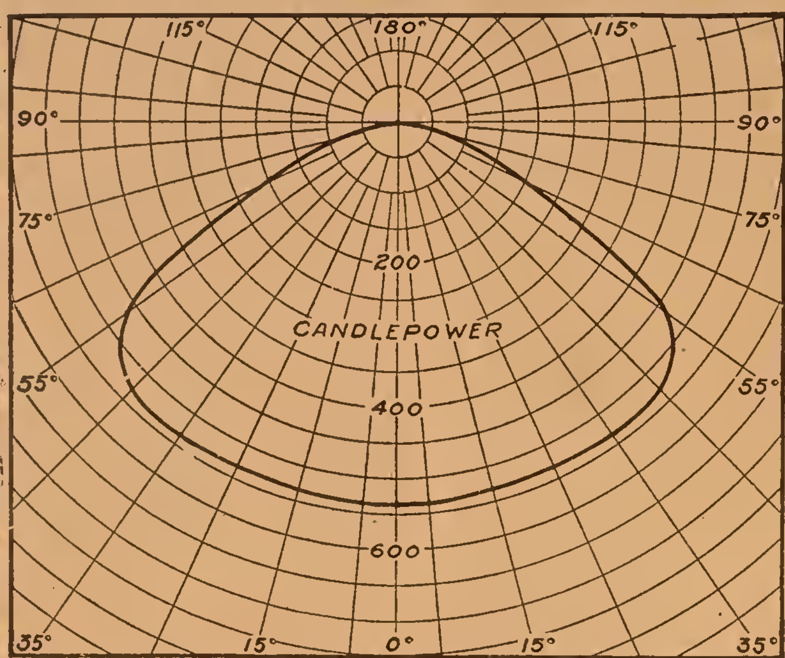


Porcelain-Enameled RLM Dome

Opal Cap

Zone	Lumens	% Total Clear Lamp
0°-60°	1548	53
0°-90°	1928	66

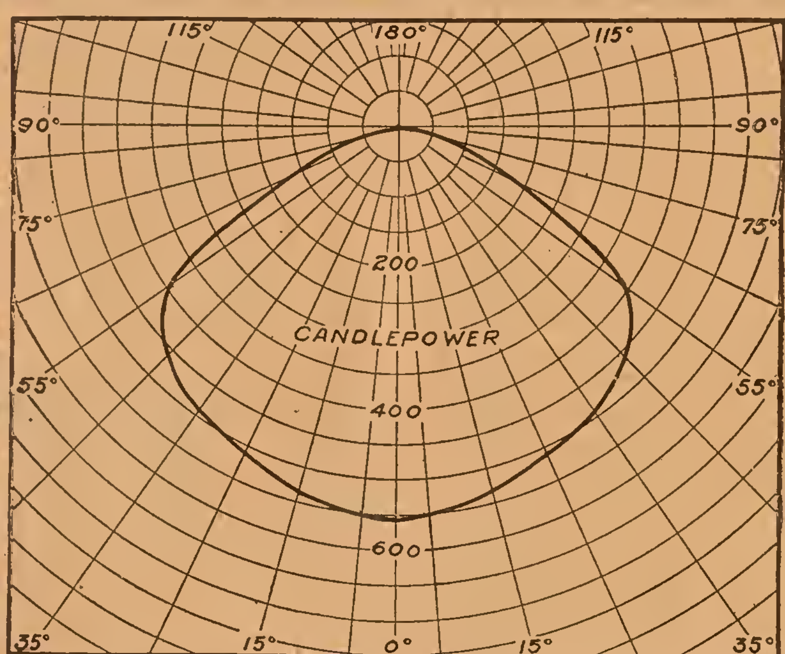
Fig. 30—Light Distribution Curve of R. L. M. Standard Dome. (See Fig. 5.)



Porcelain-Enameled Bowl

Clear Lamp

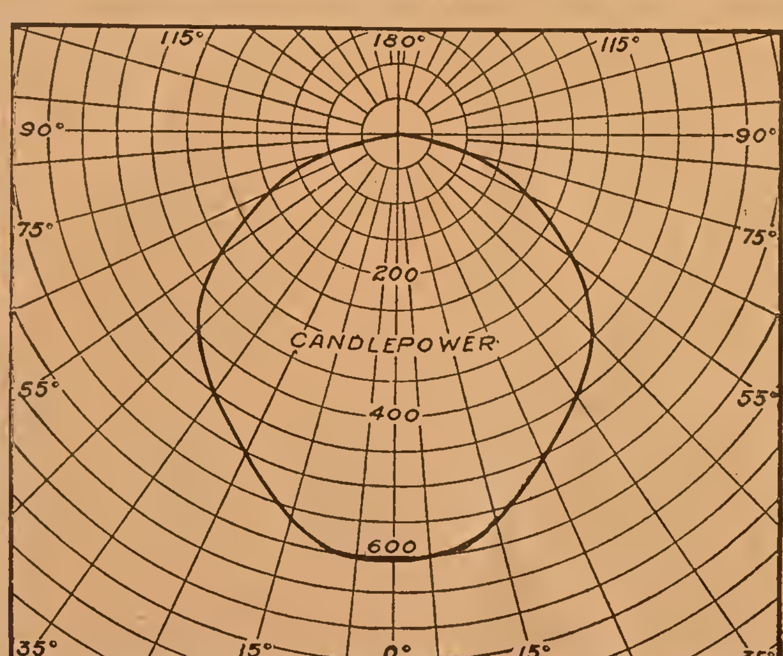
Zone	Lumens	% Total Clear Lamp
0°-60°	1605	55
0°-90°	1900	65



Porcelain-Enameled Bowl

Bowl Frosted Lamp

Zone	Lumens	% Total Clear Lamp
0°-60°	1490	51
0°-90°	1750	60



Metal-Cap Diffuser

Silver Cap

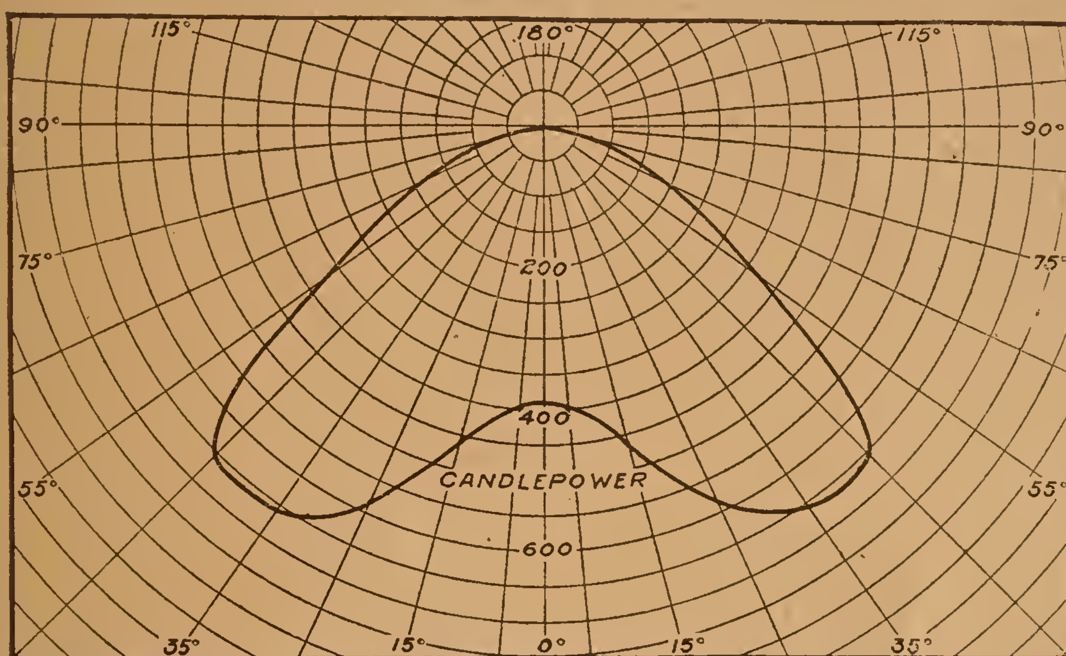
Zone	Lumens	% Total Clear Lamp
0°-60°	1285	44
0°-90°	1605	55

Fig. 31—Light Distribution Curves of Deep-Bowl Porcelain-Enameled and Large Shallow Bowl—Lamp Fitted with Polished Metal Cap. (See Figs. 7 and 9.)

Mirrored Glass

Clear Lamp

Zone	Lumens	% Total Clear Lamp
0°-60°	1750	60
0°-90°	1985	68



Prismatic Industrial

Clear Lamp

Zone	Lumens	% Total Clear Lamp
0°-60°	1840	63
0°-90°	2130	73
90°-180°	525	18
120°-180°	292	10
0°-180°	2660	91

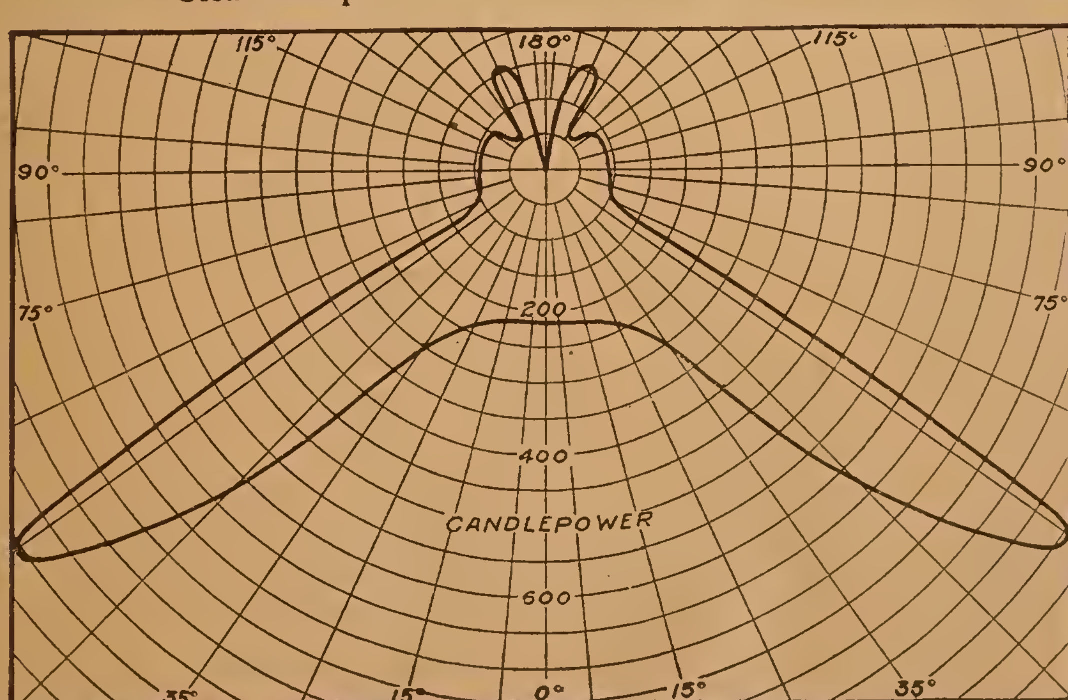


Fig. 32—Light Distribution Curves of Mirrored Glass and Prismatic Glass Reflectors. (See Figs. 11 and 12.)